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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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Engineer Desires Change. Holds First-class Board of Trade Certificate. Has had number of years' experience as foreman.—Address, K 44, Offices of ENGINEERING.

CIRCULAR-ARC BOW-GIRDER.

By WILLIAM KNIGHT.

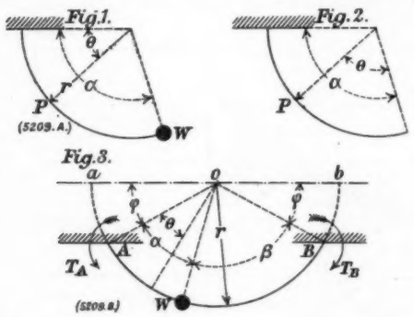
THE object of the present paper is to give in abstract a number of formulæ published by A. H. Gibson and E. G. Ritchie in "A Study of the Circular-Arc Bow-Girder," London, 1914, a book exceptionally good, which deserves being well known.

The mathematical derivation of the formulæ has been left out, and only those formulæ of interest to the designer have been reproduced below.

Diagrams are also given which will be found very helpful in solving these formulæ.

The problem to be considered is that of a girder, built into supports at one or both ends, and forming an arc of a circle in plan, which is subject at each section, to both bending and twisting.

The investigation is based on the theorem that in a straight beam, fixed horizontally at some point, the slope at any other point is given by the area of the $\frac{M}{E\,I}$ diagram between the two points.



Several cases arise, viz. :—

CONCENTRATED LOAD AT THE END (SEE FIG. 1).

M_θ and T_θ = bending and twisting moments at P.
E and C = moduli of elasticity in tension and shear.
I and J = moments of inertia of uniform cross-section about the axis of bending and twisting.
y = vertical deflection.

$$T_\theta = W r[1-\cos(\alpha-\theta)];\quad M_\theta = W r \sin(\alpha-\theta).$$

$$y_\theta = \frac{W r^3}{2\,E\,I}[\theta\cos(\alpha-\theta)-\cos\alpha\sin\theta]+\frac{W r^3}{2\,C\,J}[2(\theta-\sin\theta)+\theta\cos(\alpha-\theta)+\sin(\alpha-\theta)+\sin\alpha(\cos\theta-2)].$$

At the free end, when $\theta = \alpha$,

$$y_\alpha = \frac{W r^3}{2}\left[\frac{\alpha-\cos\alpha\sin\alpha}{E\,I}+\frac{3\alpha-4\sin\alpha+\sin\alpha\cos\alpha}{C\,J}\right]$$

If $\alpha = 90^0 = \frac{\pi}{2}$

$$y_\alpha = \frac{W r^3}{2}\left[\frac{\pi}{2\,E\,I}+\frac{1.5\,\pi-4}{C\,J}\right] = W r^3\left[\frac{0.7854}{E\,I}+\frac{0.3562}{C\,J}\right].$$

UNIFORMLY DISTRIBUTED LOAD (SEE FIG. 2).

Calling

w = uniform load in lb. per unit of length

we have

$$M_\theta = w r^2(1-\cos\theta);\quad T_\theta = w r^2(\theta\sin\theta)$$

$$y_\theta = \frac{w r^4}{2\,E\,I}\left[2-2\cos(\alpha-\theta)+\sin\theta(\alpha-\theta)+\cos\alpha-\cos\theta+\frac{\sin\theta\sin 2\alpha}{2}-\frac{\cos^3\alpha-\cos^3\theta}{3}-\cos\theta\sin^2\alpha+\frac{\alpha-\theta}{2}-\frac{\sin 2\alpha-\sin 2\theta}{4}\right]+\frac{w r^4}{2\,C\,J}\left[2-2\cos(\alpha-\theta)-2\alpha\sin(\alpha-\theta)+\alpha^2-\theta^2+(\alpha-\theta)\sin\theta+\cos\alpha-\cos\theta-\frac{\sin\theta\sin 2\alpha}{2}+\frac{\cos^3\alpha-\cos^3\theta}{3}+\cos\theta\sin^2\alpha-\frac{\alpha-\theta}{2}+\frac{\sin 2\alpha-\sin 2\theta}{4}\right].$$

At the free end, where $\theta = 0$, the deflection becomes

$$y_\alpha = \frac{w r^4}{2\,E\,I}\left[1-\cos\alpha-\frac{\cos^3\alpha-1}{3}-\sin^2\alpha+\frac{\alpha}{2}+\frac{\sin^2\alpha}{4}\right]+\frac{w r^4}{2\,C\,J}\left[1-\cos\alpha-2\alpha\sin\alpha+\alpha^2+\frac{\cos^3\alpha-1}{3}+\sin^2\alpha-\frac{\alpha}{2}+\frac{\sin 2\alpha}{4}\right].$$

If $\alpha = 90$ deg. $= \frac{\pi}{2}$ the deflection at the free end becomes

$$y = w r^4\left[\frac{0.5594}{E\,I}+\frac{0.1035}{C\,J}\right].$$

CIRCULAR-ARC GIRDER, BUILT IN AT TWO ENDS, WITH A SINGLE LOAD (SEE FIG. 3).

Formulæ for bending and twisting moments are given below.

T_A, T_B, M_A, M_B = TWISTING AND BENDING MOMENT AT "A" AND "B."
R_A and R_B = reactions at "A" and "B."
I = moment of inertia of section.
J = polar moment of inertia of section.
r = radius on neutral axis.
W = concentrated load.
E and C = moduli of elasticity in tension and shear.

BENDING AND TWISTING MOMENT AT ANY POINT "C."

$$M_\theta = M_A\cos\theta - R_A r\sin\theta + T_A\sin\theta.$$
$$T_\theta = T_A\cos\theta + R_A r(1-\cos\theta) - M_A\sin\theta.$$

Values of M_A, M_B, R_A for any value of $\frac{E\,I}{C\,J}$ can be obtained by interpolation of the values obtained from the two sets of curves shown: $R_B = W - R_A$.
For deflection formulæ see below, Fig. 6.

In these formulæ there are six unknowns: M_A, M_B, T_A, T_B, R_A, R_B. The values of these six unknowns can be obtained from the diagrams, Figs. 4 and 5, when W, a, ϕ, r, I, J, E, C, are known. The bending and the twisting moments at A and B depend somewhat on the relative value of E I and C J, except when the load is in the middle of the span. A comparison of the two diagrams shows that an increase in the ratio $\frac{E\,I}{C\,J}$ is accompanied by an increase of all the fixing moments. The effect on the values of M_A and M_B, and of the end reactions, produced by a large variation of this ratio is, however, very small, especially when a is large. The effect on the end torques is more pronounced, particularly for small values of a. The deflections for different positions of the load may be taken from Figs. 7 and 8, to which Fig. 6 is a key.

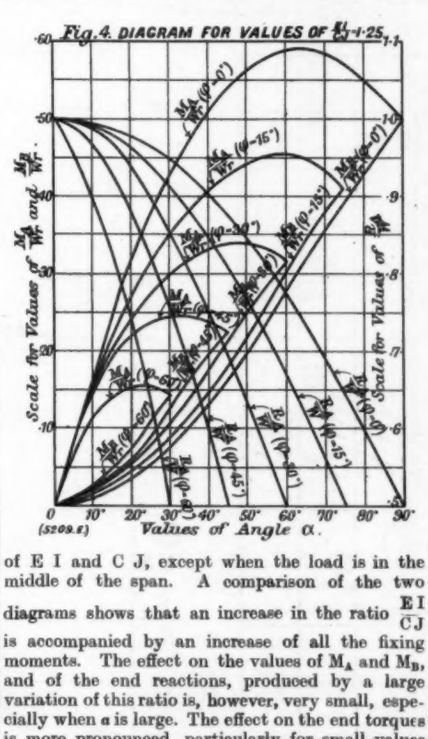


Fig.4. DIAGRAM FOR VALUES OF EI/CJ=1·25.
Scale for Values of $\frac{M_A}{W r}$ and $\frac{M_B}{W r}$
Scale for Values of $\frac{R_A}{W}$
Values of Angle α.
(5209.E.)

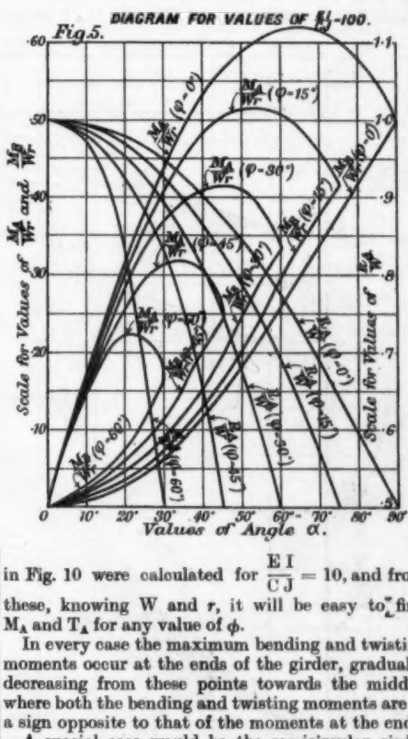
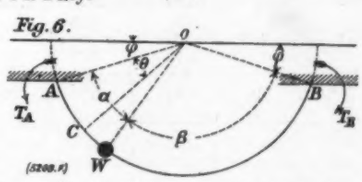


DIAGRAM FOR VALUES OF EI/CJ=100.
Fig.5.
Scale for Values of $\frac{M_A}{W r}$ and $\frac{M_B}{W r}$
Scale for Values of $\frac{R_A}{W}$
Values of Angle α.



DEFLECTION AT A POINT DISTANT θ FROM "A" AND COMPRISED BETWEEN "A" AND "W."

$$y_\theta = \frac{r^2}{2\,E\,I}[M_A\theta\sin\theta-(R_A r-T_A)(\sin\theta-\theta\cos\theta)]+\frac{r^2}{2\,C\,J}[(T_A-R_A r)(\sin\theta-\theta\cos\theta)+2R_A r(\theta-\sin\theta)+M_A(\theta\sin\theta+2\cos\theta-2)],$$

where the angle θ is expressed in function of π.
For a point between "B" and "W" distant θ from "B" substitute M_B, R_B, T_B to M_A, R_A, T_A in the above formula. For the deflection at the load substitute the angle "a" to θ in the above formula.
For values of M_A, M_B, R_A, R_B see Figs. 4 and 5.

CIRCULAR-ARC GIRDER, BUILT IN AT BOTH ENDS, WITH A UNIFORMLY DISTRIBUTED LOAD. (SEE FIG. 9).

Formulæ for this case are appended to Fig. 9, page 57. In these formulæ for bending, twisting moment and deflection at any point we have two unknowns: T_A and M_A. In this case, as in the previous one, M_A and T_A depend more or less on the value of the ratio $\frac{E\,J}{C\,J}$, except in the case of the semicircular girder ($\phi = 0$), in which M_A and T_A are independent of the value of $\frac{E\,I}{C\,J}$ (same as in the case of the girder with a concentrated load in the middle of the span).

The effect of the increase of $\frac{E\,I}{C\,J}$ is in the same direction as in the previous case (corresponding increase of bending and twisting moment; the increase being more pronounced in the twisting moment than in the bending moment), but the magnitude is so small for a large increase of the ratio $\frac{E\,I}{C\,J}$ that for every practical purpose the values of M_A and T_A can be considered as being independent of the value of $\frac{E\,I}{C\,J}$. The two curves shown in Fig. 10 were calculated for $\frac{E\,I}{C\,J} = 10$, and from these, knowing W and r, it will be easy to find M_A and T_A for any value of ϕ.

In every case the maximum bending and twisting moments occur at the ends of the girder, gradually decreasing from these points towards the middle, where both the bending and twisting moments are of a sign opposite to that of the moments at the ends.

A special case would be the semicircular girder ($\phi = 0$) built in at both ends, and formulæ covering this case are given in the letterpress accompanying Fig. 9.

CIRCULAR GIRDER WITH UNIFORM LOADING AND CENTRAL SUPPORT.

The simplest case would be a 180 deg. girder ($\phi = 0$). See Fig. 11.

Let P be the reaction on the support, applying the formulæ given before for the case of a girder with a single load between supports (see Figs. 4 and 5 and 6 and 7, where W = P and M_A and T_A have the values given by the curves corresponding to a value of $a = 90$ deg.

The deflection in the middle due to a load P is given by

$$P r^3\left(\frac{0.4674}{2\,E\,I}+\frac{0.0382}{2\,C\,J}\right).$$

The downward deflection at the centre due to the loading as in Fig. 9, is

$$w r^4\left[\frac{0.7272}{2\,E\,I}+\frac{0.053}{2\,C\,J}\right].$$

Equating these two values we find the reaction on the support

$$P = w r\left(\frac{0.7272\,C\,J+0.053\,E\,I}{0.4674\,C\,J+0.0382\,E\,I}\right).$$

The value of M_θ and T_θ just as in the precedent

cases, depends on the value of the ratio $\frac{E I}{C J}$.

For $\frac{E I}{C J} = 1.25$ (circular section) we have $P = 1.54\ w r$

$$M_\theta = w r^2 (1 - 0.77 \cos\theta - 0.783 \sin\theta),$$
$$T_\theta = w r^2 (0.801 - 0.783 \cos\theta + 0.77 \sin\theta - \theta),$$

For $\frac{E I}{C J} = 10$ we have $P = 1.47\ w r$

$$M_\theta = w r^2 (1 - 0.735 \cos\theta - 0.805 \sin\theta),$$
$$T_\theta = w r^2 (0.835 - 0.805 \cos\theta + 0.735 \sin\theta - \theta).$$

For intermediate values of $\frac{E I}{C J}$ interpolate the numerical constants given in the above formulæ.

For a girder subtending an angle less than 180 deg. the problem may be solved in an exactly similar manner.

Circular Girder with Uniform Loading and Two Supports (See Fig. 12).

Let M''_A, T''_A, R''_A represent such end conditions at A as would be produced by two concentrated loads P at C and D, and let M'_A, T'_A, R'_A represent such end conditions as would be produced by the uniform load only, with supports removed.

Under these conditions the downward deflection at C and D, due to the uniform loading, would be obtained by using the formula for y below, Fig. 9, using γ instead of θ and M'_A, T'_A, R'_A instead of M_A, T_A, R_A. $R'_A = w\left(\frac{\pi}{2} - \phi\right)$ and M'_A and T'_A for the particular value of ϕ would be obtained from the curves shown in Fig. 10.

Next, consider the girder as being subject to two upward forces P at C and D. The values of M''_A, T''_A, R''_A are the sum of the corresponding values produced by each of the two symmetrical forces P, and may evidently be obtained by adding the values of M_A and M_B R_A and R_B T_A and T_B, as obtained from Figs. 4 and 5 and 7 and 8 for a girder having the proper value of ϕ and for $\gamma = a$. On substituting these values obtained from the curves, each of which is expressed in terms of P, in the equation for y given below, Fig. 6, and equating this to the value of y as found before when the supports were assumed to have been removed, the resultant expression contains P as the only unknown, and can be easily calculated.

Semicircular Girder with Uniform Loading and Two Supports at 60 deg. from the Ends.

This is a particular case of the general one given before. By going through the same process as illustrated above we obtain:

$$P = w r \left[\frac{0.564\ C J + 0.037\ E I}{0.539\ C J + 0.035\ E I}\right]$$

and taking $\frac{E I}{C J} = 1.25$

$$P = 1.05\ w r$$
$$R_B = R_A = 0.521\ w r$$
$$M_B = M_A = 0.091\ w r^2$$
$$T_B = T_A = 0.001\ w r^2$$

The state of affairs at any point distant θ from 0 A is, for points between A and C is represented by:

$$M_\theta = w r^2 (1 - 0.909 \cos\theta - 0.52 \sin\theta)$$
$$T_\theta = w r^2 (0.521 - 0.52 \cos\theta + 0.909 \sin\theta - \theta)$$

and between C and the centre:

$$M_\theta = w r^2 (1 - 1.045 \sin\theta)$$
$$T_\theta = w r^2 (1.571 - 1.045 \cos\theta - \theta).$$

Semicircular Girder with Uniform Loading and Two Supports at 45 deg. from the Ends.

For $\frac{E I}{C J} = 1.25$ we have:

$$P = 1.46\ w r \qquad M_A = -0.031\ w r^2$$
$$R_A = R_B = 0.111\ w r \qquad T_A = 0.01\ w r^2$$

As before, between A and C:

$$M_\theta = M_A \cos\theta - (R_A r - T_A)\sin\theta + w r^2 (1 - \cos\theta)$$
$$T_\theta = (T_A - R_A r)\cos\theta + R_A r - M_A \sin\theta - w r^2 (\theta - \sin\theta$$

while between C and the centre:

$$(M_\theta = M_A \cos\theta - (R_A r - T_A)\sin\theta - P r \sin(\theta - 45°) + w r^2 (1 - \cos\theta$$
$$T_\theta = (T_A - R_A r)\cos\theta + R_A r - M_A \sin\theta +$$
$$P r [1 - \cos(\theta - 45°)] - w r^2 (\theta - \sin\theta).$$

Semicircular Girder with Uniform Loading, Built in at the Ends and Supported at the Centre by the End of a Cantilever (Elastic Support).

First find deflection at centre with support removed. Then find deflection at centre due to a force P. Call k P the actual deflection of the girder at the support:

Fig. 7.

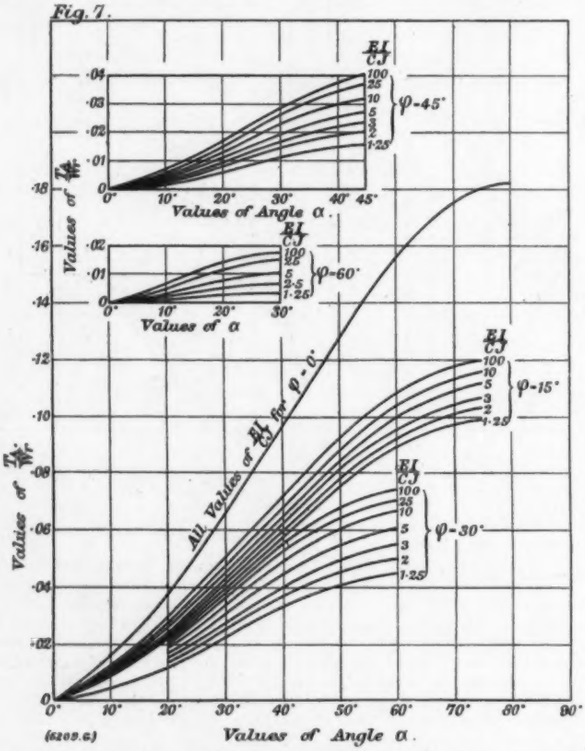
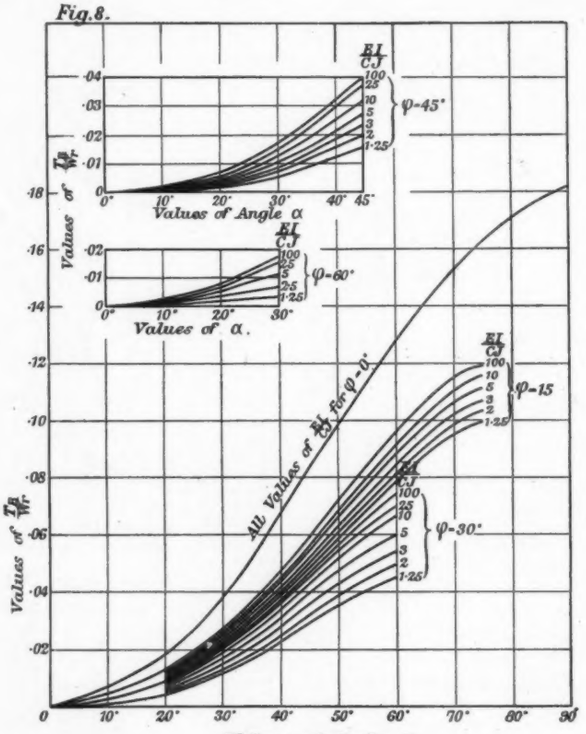


Fig. 8.



The following table shows how the fixing moments and reactions vary with the ratio $\frac{E I}{C J}$:—

$\frac{E I}{C J}$	P	R_A	M_A	T_A
1·25	1·05 $w r$	0·521 $w r$	0·091 $w r^2$	0·001 $w r^2$
100	1·06 $w r$	0·511 $w r$	0·081 $w r^2$	−0·002 $w r^2$

From this table it appears that a considerable change in this ratio has a very little effect on the magnitude of the fixing moments.

The influence of intermediate supports on the value of the maximum bending and twisting moment is given by the table:—

——	*Number of Supports.* None.	One at Centre.	Two at 60 deg.
Maximum bending moment..	1	0.26	0.09
Maximum twisting moment..	1	0.11	0.035

Deflection of support with support removed $= w r^2 \left(\frac{0.7272}{2 E I} + \frac{0.053}{2 C J}\right)$

Actual deflection at support $= k P$

Upward deflection at centre due to P $= P r^3 \left[\frac{0.4674}{2 E I} + \frac{0.0382}{2 C J}\right]$

$$P r^3 \left(\frac{0.4674}{2 E I} + \frac{0.0382}{2 C J}\right) + k P = w r^4 \left(\frac{0.7272}{2 E I} + \frac{0.053}{2 C J}\right)$$

from which the reaction at the elastic support is found:

$$P = w r \frac{0.7272 + 0.053 \frac{E I}{C J}}{0.4674 + 0.0382 \frac{E I}{C J} + \frac{2 k E I}{r^3}}$$

When $k = \frac{l^3}{3 E I_1}$ (in the case of a cantilever of uniform section, having the moment of inertia of section $= I_1$ and length $= l$)

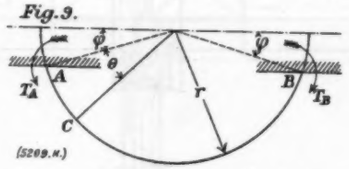
$$P = w r \frac{0.7272 + 0.053 \frac{E I}{C J}}{0.4674 + 0.0382 \frac{E I}{C J} + \frac{2 l^3 I}{3 r^3 I_1}}$$

Experimental Verification of Formulæ.

The following are the results of experiments made in order to check the formulæ given:—

Type of Section	Conditions of Test.	Angle Subtended by Arc.	Deflection. Measured.	Deflection. Calculated.
		deg.	in.	in.
Circular	Circular arc cantilever with load at free end	90	1.469	1.475
		135	4.475	4.475
Circular	Ditto with uniform loading	90	0.510	0.502
Circular	Semi-circular bow girder fixed at ends with single load at α from one end, deflection at load	$\alpha = 30$	0.043	0.043
		$\alpha = 45$	0.117	0.115
		$\alpha = 60$	0.202	0.204
		$\alpha = 90$	0.307	0.307
Circular	Circular arc girder with single weight at centre	120	0.075	0.074
Circular	Ditto with uniform loading	180	0.310	0.306
Angle	Circular arc girder with weight at centre	90	0.011	0.012
		180	0.124	0.116
Angle	Semi-circular bow girder with single load at 45 deg. from one end	Deflection at weight	0.036	0.032
Angle	Ditto ditto	Deflection at centre	0.068	0.072

Fig.9.



UNIFORMLY LOADED CIRCULAR ARC GIRDER.

W = uniform load per unit of length.
$T_A = T_B$; $M_A = M_B$ = twisting and bending moments at "A" and "B."

$R_A = R_B = w r \left(\frac{\pi}{2} - \phi\right)$ = reactions at "A" and "B."

I = moment of inertia of section.
J = polar moment of inertia of section.
r = radius on neutral axis.
E and C = moduli of elasticity in tension and shear.
θ angle expressed in function of "r."

BENDING AND TWISTING MOMENT AT ANY POINT "C."

$M_\theta = M_A \cos\theta - R_A r \sin\theta + T_A \sin\theta + w r^2 (1 - \cos\theta)$.

$T_\theta = T_A \cos\theta + R_A r (1 - \cos\theta) - M_A \sin\theta - w r^2 (\theta - \sin\theta)$.

DEFLECTION AT ANY POINT "C."

$$y_\theta = \frac{r^2}{2EI}[(M_A - w r^2)\theta \sin\theta - (R_A r - T_A)(\sin\theta - \theta\cos\theta) - 2 w r^2 (\cos\theta - 1)] + \frac{r^2}{2CJ}[(T_A - R_A r)(\sin\theta - \theta\cos\theta) + (M_A - w r^2)(\theta \sin\theta + 2\cos\theta - 2) + 2 R_A r (\theta \sin\theta) - 2 w r^2 \left(\frac{\theta^2}{2} + \cos\theta - 1\right)]$$

SEMI-CIRCULAR GIRDER UNIFORMLY LOADED ($\phi = 0$).

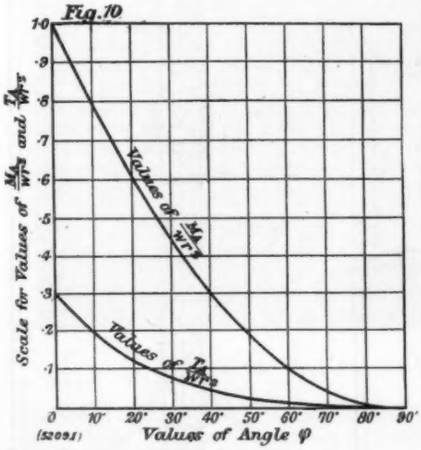
$M_A = M_B = w r^2$; $R_A = R_B \frac{\pi}{2} w r$; $T_A = T_B = w r^2 \frac{2}{\pi}\left(\frac{\pi^2}{4} - 2\right)$

$M_\theta = w r^2 (1 - 1.2728 \sin\theta)$; $T_\theta = w r^2 (1.5708 - 1.2728 \cos\theta - \theta$.

DEFLECTION AT THE CENTRE.

$$y = w r^4 \left(\frac{0.7272}{2EI} + \frac{0.053}{2CJ}\right)$$

Fig.10



CIRCULAR GIRDER BUILT IN AT THE ENDS, WITH UNIFORM LOADING AND WITH THREE INTERMEDIATE SUPPORTS.

Let the supports be arranged symmetrically, P_1 and P_2 being the reactions at the outer supports and Q that at the central support. These reactions may be obtained by expressing the facts: (1) That the downward deflection at the centre due to the loading is equal to the sum of the upward deflections at the centre due to the forces P_1, P_2 and Q in their respective positions; (2) that the downward deflection at P_1, due to the loading, is equal to the upward deflection at this point due to P_1, P_2 and Q.

Thus, if P_1 and P_2 are each at 45 deg. from the ends, we have:

Downward deflection at Q due to loading	$= w r^4 \left(\frac{0.7272}{2EI} + \frac{0.053}{2CJ}\right)$
Downward deflection at P_1 and P_2 due to loading	$= w r^4 \left(\frac{0.3328}{2EI} + \frac{0.0213}{2CJ}\right)$
Upward deflection at Q due to force Q	$= Q r^3 \left(\frac{0.4674}{2EI} + \frac{0.0382}{2CJ}\right)$
Upward deflection at Q due to force P_1 and $P_2 = P$	$= 2 P r^3 \left(\frac{0.211}{2EI} + \frac{0.0594}{2CJ}\right)$
Upward deflection at P_1 due to force P_1	$= P r^3 \left(\frac{0.1865}{2EI} + \frac{0.0055}{2CJ}\right)$
Upward deflection at P_1 due to force P_2	$= P r^3 \left(\frac{0.0845}{2EI} + \frac{0.0085}{2CJ}\right)$
Upward deflection at P_1 due to force Q	$= Q r^3 \left(\frac{0.2297}{2EI} + \frac{0.015}{2CJ}\right)$

Fig.11.

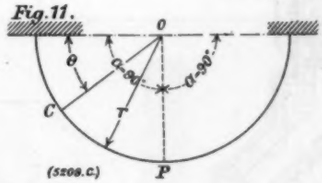
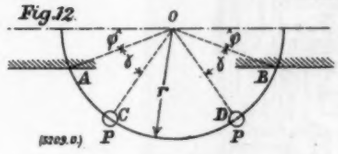


Fig.12.



Collecting and equating deflections at same points we get:

$$w r (0.7272\,CJ + 0.053\,EI) = Q(0.4674\,CJ + 0.0382\,EI) + P(0.422\,CJ + 0594\,EI)$$

$$w r (0.3928\,CJ + 0.0213\,EI) = Q(0.2297\,CJ + 0.015\,EI) + P(0.2710\,CJ + 0.014\,EI)$$

when $P = P_1 = P_2$. If $EI \div CJ = 1.25$:

$Q = 0.74\,wr$; $P = 0.83\,wr$; $R_A = R_B = \frac{1}{2}(\pi wr - Q - 2P) - 0.37\,wr$;

$M_A = M_B = \frac{2 w r^2 - 2 P r \sin 45° - Q r}{2} = 0.044\,wr^2$; $T_A = 0.001\,wr^2$.

NEW RAILWAY TARIFFS IN AUSTRIA-HUNGARY.—On January 1 a new goods tariff came into operation on the Austrian railways as well on those of Hungary, Bosnia and Herzegovina. The difficult problem of bringing into force increased tariffs in the midst of the present industrial and commercial conditions has, it would seem, been solved in a satisfactory manner, so much so that the change has attracted considerable attention in Germany. The increases of tariffs which have taken place in most countries have often failed to do justice to the very varying commodities carried. The Austrian railways have, so far, got over these difficulties by removing all goods to the next class above their present tariff level. This move has tended to approximate the Austrian tariff to that of Germany, although the unification which is no doubt one of the aims of the promoters of the great Central European State Trust, has not yet been achieved. By a number of goods in the Austro-Hungarian railways being raised from class II. to class I. the charges will be made to correspond much better with those of German tariff for similar goods. There are however, several important exceptions to the impending elevation from Class II. to Class I., as for instance grain, sugar, coal, &c. As the goods belonging to Class I. could not be raised to a higher tariff class, the rates for such goods have been raised 50 per cent., so have those for ordinary express goods. The Austro-Hungarian railway revenue will be further swelled (and for some lines this is highly desirable) by a working expense fee or charge, which is irrespective of distance, and consequently will particularly affect the short distance traffic. This new charge takes the shape in an increase in fees for warehousing, hire of wagons, reloading, &c., all of which also will be made to apply to the Austrian private railways. The Austrian passenger fares are also to be raised materially to put a stop to much avoidable or entirely unnecessary travelling. Efforts are again being made to cause the State to take over the South railway, which is in a very bad way. But the time is hardly propitious for such a transfer, inasmuch as the railways gold indebtedness would also have to be provided for, in addition to which an understanding will have to be arrived at with Hungary as to the Hungarian lines of the concern.

MODERN METHODS FOR THE STORAGE OF COAL.

By GEORGE FREDERICK ZIMMER, A.M.Inst.C.E.

(*Concluded from page 32.*)

Method II.—We will now deal with the subject of accumulating coal in such a way that it can be reclaimed from the base of the pile. This method is more scientific, and has the advantage that not only is accumulation of the small coal prevented, but that the coal at the deepest part of the pile is kept just sufficiently in motion for the bulk to be slightly broken every time coal is withdrawn, two advantages which minimise spontaneous combustion, and therefore make a deeper or higher pile admissible with a sufficient degree of safety. This is important if the available storage area is limited, as is often the case in gas works within the precincts of large cities.

Fig.14.

Fig.15.

Fig.16.

Fig.17.

Fig.18.

Fig.19.

Fig.20.

Fig.21.

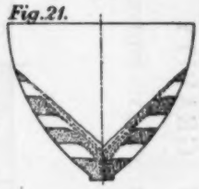


Fig.22.

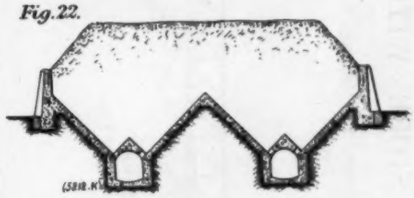
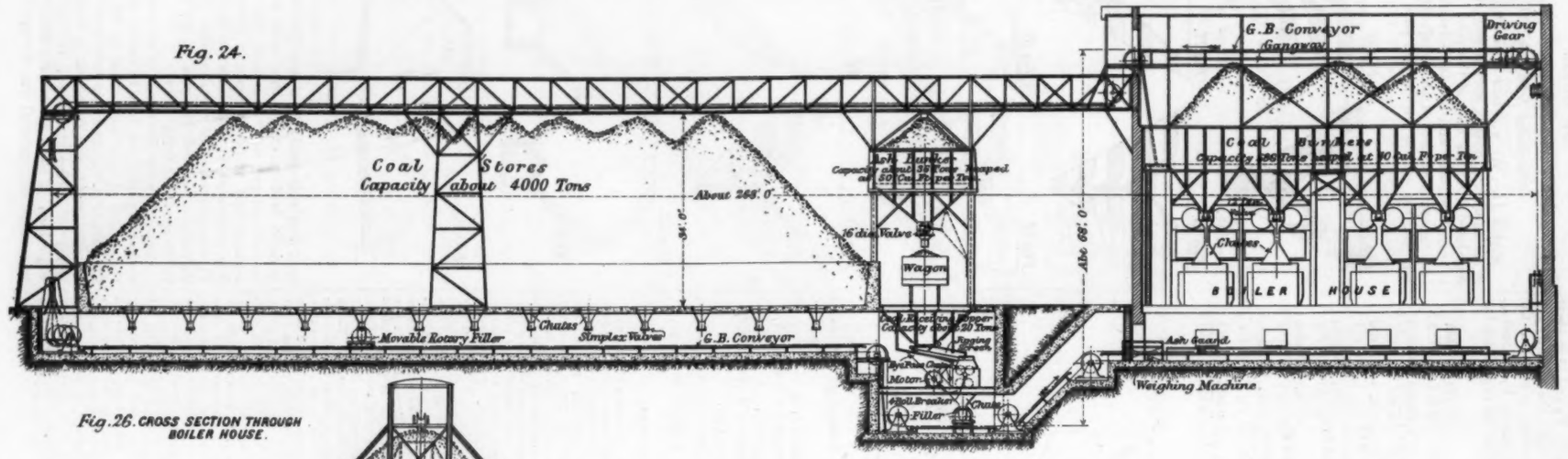


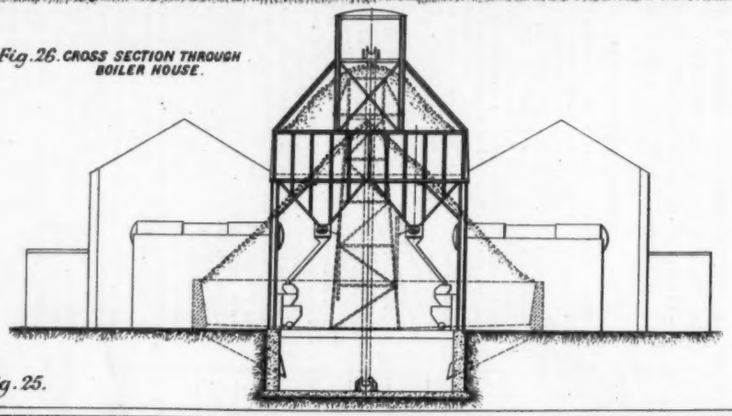
Fig.23.

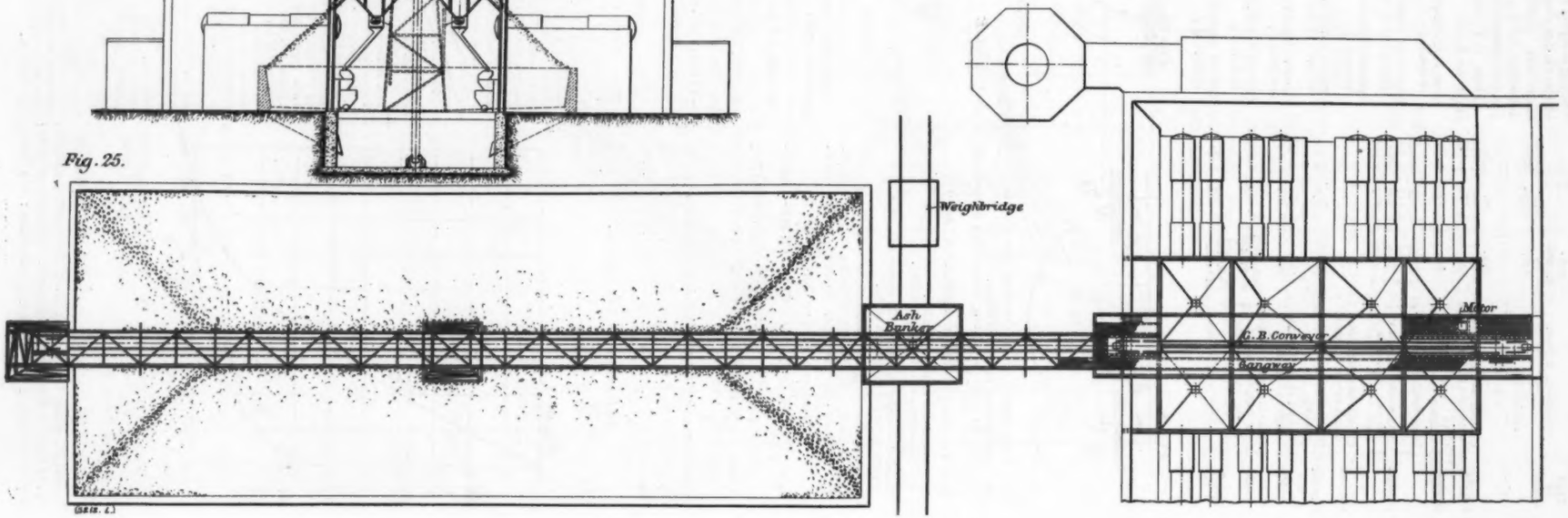
Concerning the movement of the coal in a hopper pocket, it might not here be out of place to record the results of some tests made by the writer. The diagram, Fig. 14, shows the movement of a granular material, which was deposited in alternate vertical layers of different colour, during withdrawal; while Figs. 15 to 17 show three stages of a similar test where the material was arranged in alternate

COAL STORE WITH GRAVITY BUCKET CONVEYOR.

CONSTRUCTED BY MESSRS. BABCOCK AND WILCOX, LIMITED, ENGINEERS, LONDON.







horizontal layers. The movement in bunkers of the form now frequently employed is shown in Figs. 18, 19, 20 and 21.

As the diameter of the descending column in the bunker depends upon the size of the outlet, it is well to make this as large as possible and withdraw the coal relatively slowly by employing mechanical feeding devices. A large outlet is advantageous for a twofold object: namely, the slowly-descending column of coal will have a ventilating or cooling effect if there should be a tendency to heat, and a larger outlet will prevent, or at least lessen, the tendency for large pieces to bridge or cave and cause a stoppage in the coal supply through the outlet.

The diagrams give a very clear picture of what takes place, and if the sides of the hoppers are chosen of a more shallow, or even a somewhat more acute angle it will not alter the proceedings; as soon as a funnel-shaped depression has been formed of the angle of repose of the coal, the pieces round the crater will roll down and descend.

The experiments were made with a model having a glass front, but in actual practice the same process can be proved to actually take place, for if the upper layer of coal is limewashed, this washed surface will not be disturbed beyond the formation of a crater, *i.e.*, the central column will be withdrawn from the bunkers before the whitewashed pieces begin to descend, and they will presently appear through the outlet. This shows us, incidentally, that the coal deposited last in the bunker will mix with some of that stowed earlier, so that we might almost depend on having in the descent an average sample of the contents of the bunker, provided the outlet is big enough. Where gas pipes are used in such coal stores for the reception of thermometers—to record any change in the temperature—these pipes remain in an upright position as the coal-level in the bunker becomes lower, until practically two-thirds of the coal which used to hold them has been withdrawn.

Fig. 27.

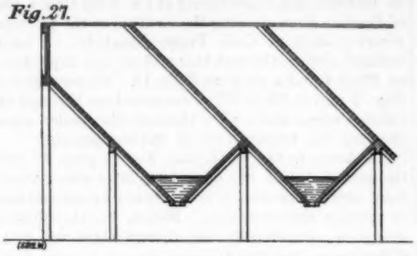
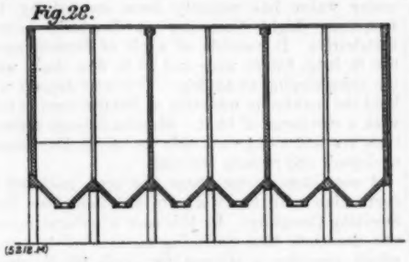


Fig. 28.



FIGS. 27 AND 28. RANK SYSTEM OF COAL SILOS

It has already been suggested that a base for a coal store, like Fig. 10, on page 32 *ante*, will facilitate the picking up from above and save trimming. If we develop this idea slightly, as shown in Fig. 22, on page 57, we have one of the most obvious solutions of a coal store consisting of a ferro-concrete, hoppered structure, from the lowest point of which the coal can be withdrawn through openings fitted with gates which communicate with a tunnel or culvert in which some kind of conveyor is located. Bunkers of steel structure instead of ferro-concrete have lately been used; they have the advantage of being lighter, and are therefore more suitable for erection on alluvial soil. Such a bunker is shown in Fig. 7, on Plate V, published last week.

In all installations of this kind the surface and rain-water is sometimes difficult to keep out unless a large drain at a sufficiently low level is or can be made available; this trouble can partly be coped with if the rain-water is kept out by roofing the whole store in. Such a roofing does not involve so large a capital outlay if a steel structure is in any case decided upon to support the mechanical means which convey the coal to the heap, and a roof can be supported with relatively little expense from such a structure. The foregoing applies to all

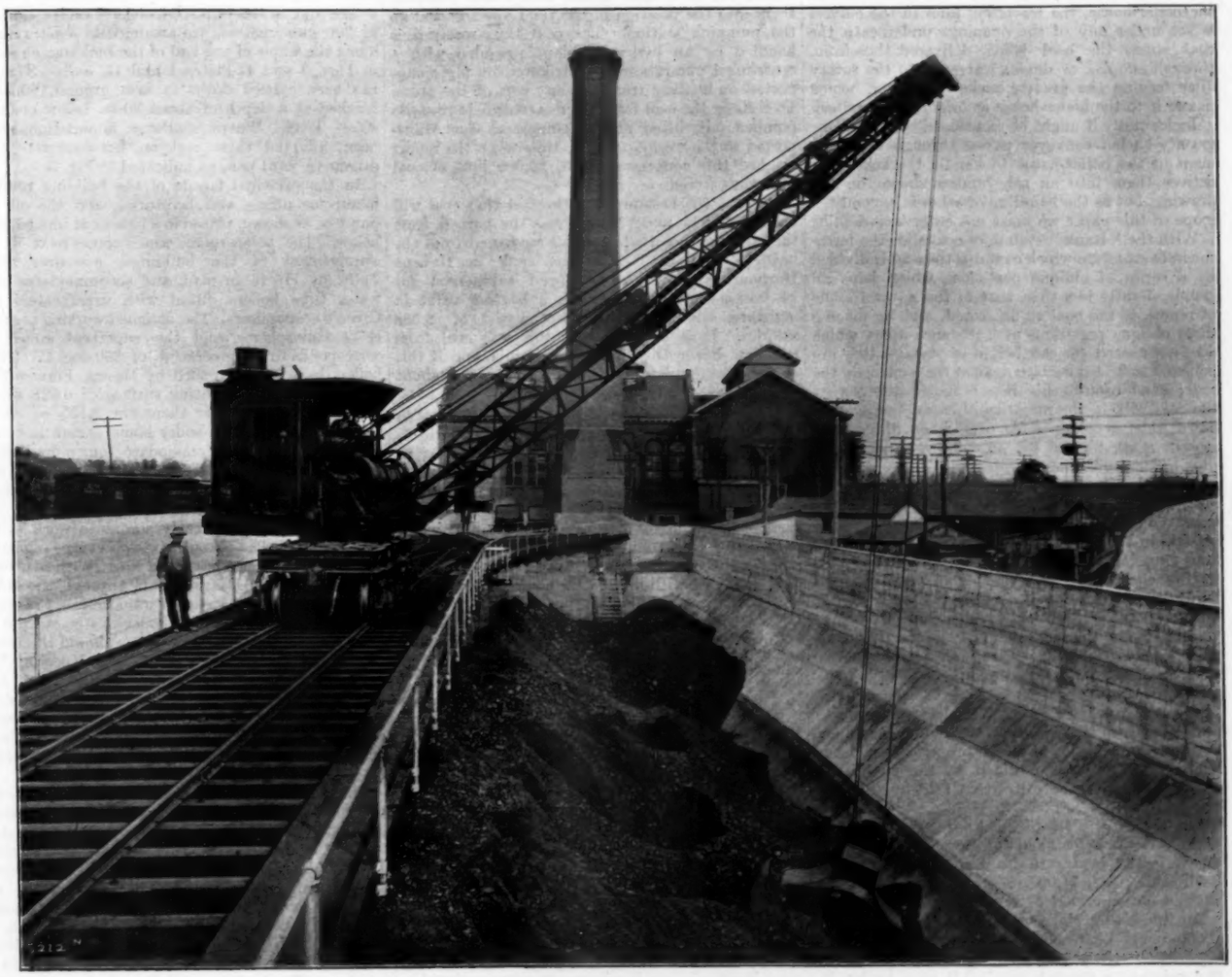


FIG. 29. COAL STORAGE UNDER WATER AT THE WORKS OF THE INDIANOPOLIS LIGHT AND HEAT COMPANY.

stores from which the coal is to be withdrawn at the base.

A much less costly plan is shown in Fig. 23; it is nearly as good as the last one, but the coal cannot all be withdrawn without some trimming, but even this defect is by some considered an advantage, as there must always be an emergency quantity left. The dotted lines represent the angle of repose of the coal, and show how much will run out automatically and how much will remain as an emergency stock.

A typical Babcock and Wilcox coal store, equipped with a gravity bucket conveyor, is shown in Figs. 24, 25 and 26, on page 58. The operation of the plant is exceedingly simple. The coal is delivered to the receiving hopper between the coal store and the boiler-house, from thence by means of a jigger through a four-roll breaker on to the rotary filler of the gravity bucket conveyor, from whence it is distributed over the coal store external to the boiler-house, dumped at any convenient point thereon, or taken direct to the bunkers in the boiler-house, as required.

If the coal from the store is to be withdrawn to the boiler-house, the travelling filler in the culvert is set under any of the openings underneath the coal store, the coal being delivered therefrom, through simplex or duplex valves, into the rotary filler feeding the gravity bucket conveyor, which passes it to the boiler-house as originally described.

Incidentally it might be mentioned that the same gravity bucket conveyor passes through the basement of the boiler-house to handle the ashes and deliver them into an ash bunker shown on the drawing, but as the handling of ashes is beyond the scope of this paper we must not enter into details.

With the "Rank" system of coal silos the ferro-concrete structure which contains the coal is divided by a series of oblique partitions which have an incline slightly less than that of the natural angle of repose of the coal to be stored, and by placing these oblique partitions at a distance apart which does not exceed the safe height of storage, they are believed to be a safeguard against the heating of the coal; in addition to this there is the advantage that the coal will, in the majority of cases, slide gently down, thus avoiding a big drop when filling such stores. Figs. 27 and 28, page 59, represent such silos in longitudinal and cross-section.

Method III. Storing Coal under Water.—Storing coal in this way is probably the most expensive, but it is undoubtedly the most economical method in the long run. About the year 1905 the first experiments were made in this country in storing coal under sea-water, and proved to be perfectly successful, as the coal thus stored suffered no deterioration. There was, curiously, a prevailing idea at the time that only sea-water would preserve coal thus, but it was found subsequently that the coal would keep equally as well in fresh water.

According to Mr. Parr: "Underwater storage prevents loss of heat values, and is not accompanied by deterioration in physical properties, such as slacking. The water retained by the coal upon removal is substantially only that held by adhesion or capillarity."

The first large plant of this kind, for storing coal under water, was installed at Chicago, where 12 pits 80 ft. by 25 ft. by 16 ft. deep were employed, holding together, 14,000 tons of coal under water, without any apparent deterioration.

An interesting plant of this kind is that of the Indianopolis Light and Heat Company, which is illustrated in the photographic view, Fig. 29, page 59. It consists of a concrete pit, 300 ft. long by 100 ft. wide by 28 ft. deep, the wall rising 10 ft. above the ground; below the ground the wall slopes at an angle of 45 deg., this being done to reduce the cost of construction. The pit is 72 ft. wide by 272 ft. long at the bottom. The concrete is from 12 in. to 18 in. thick, and is reinforced throughout with twisted ¾-in. square rods. A row of concrete piers, 15-ft. centres, extend lengthways through the centre of the pit and support a trestle which carries a standard-gauge track. The coal is handled by a Brown hoist crane and grab-bucket, operated by one man. 40-lb. rails, 18-in. pitch, are embedded in the bottom of the pit, ½ in. extending above in order to prevent the bucket striking the concrete. The pit has a capacity of 13,000 tons of coal, and is filled with water to the ground-level. Through the centre of the pit is a trough 12 ft. wide and 1 ft. deep, which serves for drainage. The pit was built to the design of Mr. Thomas A. Wynne, vice-president of the company.

The largest installation for the storage of coal under water has recently been erected by the Duquesne Light Company at Brunot's Island, Pittsburgh. It consists of a pit of ferro-concrete 800 ft. long, 150 ft. wide and 25 ft. 6 in. deep, with the sides sloping at 45 deg. This coal deposit will hold the maximum quantity of 100,000 tons of coal with a surcharge of 15 ft. Standard-gauge railway lines are laid along each side for locomotive cranes to deposit and reclaim the coal.

A coal store under water has been installed in connection with the works of the American Zinc Smelting Company. In this case a natural ravine was dammed, thus enclosing an area of 4½ acres, which provides a storage for coals 30 ft. deep. The coal is deposited in this store by running the trucks out on a steel girder bridge and dumping them into the position of the reservoir adjacent to the pumping station. The coal thus received is handled by an hydraulic plant provided with a centrifugal pump, and is distributed by pipes supported on floating trusses to any part of the store. To reclaim the coal from the reservoir it is likewise pumped out, lifted into wagons, and thus transported to the works. At the time when the report reached this country in 1914, 20,000 tons of coal were thus stored.

Perhaps the best proof of the fact that coal will keep perfectly under water may be gained from the circumstance that the coal recovered from the battleship Maine, which was sunk in Havana Harbour, and which had been submerged for 14 years, showed on analysis a heating value (a moisture, ash, and sulphur-free basis) of 8.588 calories. It is believed that this was coal from the New River District, West Virginia, and if this be the case the deterioration in 14 years was about 160 calories, or 1.9 per cent.

What we have to consider is whether the loss in heating units during an exposure for 12 months to the air is sufficient to justify so great an outlay as would be necessary for an installation to store coal under water, when other scientifically arranged stock heaps will give very good results at an infinitely smaller cost. We may say that under-water storage for this country is not likely to become popular, except perhaps in cases where a natural receptacle can, with slight modifications, be adapted.

ELECTRIC PENCIL FOR STEEL ETCHING.—An etchograph or electric pencil for writing or drawing on steel is described by William Brewster, of New York, in the *Scientific American*, of November 3rd, 1917. A small step-down transformer is energised by putting the terminals in a lamp socket. In a circuit of 110 volts and 60 cycles currents of 1.5 amperes are transformed into currents of 20 amperes and 2 volts. These currents are taken to a metal clamp on the pencil, the other connection being made with the piece of steel to be marked. The pencil is of copper, the holder is made of ebonite. The depth of the marking can be adjusted by means of a rheostat. Milling cutters, taps, drills, saws, &c., of hard steel or iron can be marked in this way, it is claimed, and this easy distinctive permanent marking of small tools should certainly be welcome in the workshop; the worker may like his own way of marking, and stuck-on labels are no good for metallic tools.

GAS-HEATED ISOTHERMAL ROOM.—In the Physical Institute of the University of Königsberg a constant temperature room had been created by providing double walls with insulating layers; the room was damp in summer, dry in winter, but never comfortable. The room was heated by hot water pipes; by adding a gas heater with automatic control a pleasant temperature is maintained within ± 0.04 deg. C. The electrically controlled gas valve (described by G. Hoffmann in the *Physikalische Zeitschrift* of July 15, 1917) has the shape of a U; the limbs are wound with coils like an electro-magnet, and the passage connecting the two limbs at the bottom is closed when the magnet is energised and a plate raised; a small pilot jet is always left burning. The control is effected by a spiral built up of strips of zinc and iron like a compensating pendulum; the spiral ends in a contact arm bearing against an adjustable screw. The device is inserted in a shunt of the lighting circuit; the gas is lighted when the temperature sinks below the normal. The device thus operates intermittently and keeps the temperature within the limits 18.1 deg. and 18.2 deg. C.

ELECTRIC POWER SUPPLY AT BUENOS AIRES.

(*Continued from page* 6.)

IN our issue of the 4th inst. we gave a brief historical survey of the inception and development of the undertaking of the Compania Italo-Argentina de Electricidad, reproducing at the same time a plan of Buenos Aires showing the location of the principal power station at Calle Pedro Mendoza. A longitudinal section through this station was reproduced on Plate I and a plan on Plate II. We now give in Figs. 5 and 6, Plate III, a cross section through the turbine room, and a plan through the boiler room, showing the arrangement of the economisers.

As shown in the small plan Fig. 2, page 5, *ante*, the power station lies close to a deep-water wharf, from which, however, it is separated by several lines of railway and tramway. Hence, for the present, stores are delivered by rail, though there will be no difficulty in arranging later on, should it prove desirable, a bridge across the rail and tram tracks, thus connecting the works directly with the ship's side.

The four oil fuel tanks, which have each a capacity of 200 cub. metres, are arranged in a pit running along the whole of one end of the building, as shown in Figs. 3 and 4, Plates I and II, *ante*. This pit has been carried down to firm ground, which is reached at a depth of about 30 ft. below ordinary street level. Where shallower foundations have been adopted these rest on ferro-concrete piles driven to hard pan, as indicated in Fig. 3.

In the principal façade of the building room is found for offices and lavatories, and the oil fuel pump is, as shown, placed in a basement immediately below. The boiler room, which comes next in the arrangement of the buildings, measures about 74 ft. by 116 ft. in plan, and accommodates eight water tube boilers, fitted with superheaters and Green's economisers. The designed working pressure is 14 atmospheres, and the superheat aimed at, corresponds to a temperature of 350 deg. C. These boilers have been supplied by Messrs. Franco Tosi. They have each a heating surface of 6,028 sq. ft. and in each economiser there are 3,445 sq. ft. of heating surface. The boiler house is now in course of enlargement to accommodate four more boilers, which will be supplied by Messrs. Babcock and Wilcox. Two more oil tanks, each of 22,950 cub. ft. capacity, are being simultaneously installed.

The use of oil fuel greatly simplifies work in the boiler house. The output of steam can be regulated in exact accordance with the load on the turbines without material loss of steam through the safety valves, and without violent fluctuations in the steam temperature. Moreover a boiler can be started up from the cold in a very short time should the necessity arise. The oil sprayers are of the Koerting-Tosi type. The boilers have steel chimneys and are operated with induced draught, the fan motor for which is clearly shown to the right of the boiler room in Fig. 3 on Plate I, published with our issue of the 4th inst. A view along the stoking alley is reproduced in Fig. 7.

The feed tank is located at one end of the boiler room below floor level, and is shown in cross section in Fig. 3, Plate I *ante*. There are three feed pumps, two of the turbine type, each capable of delivering 4,238 cubic ft. per hour, whilst the third is a reciprocating pump with a capacity of 1,413 cub. ft. per hour. A fourth feed pump on the triple expansion principle and capable of delivering 1,766 cub. ft. per hour, will shortly be installed by Messrs. Weir.

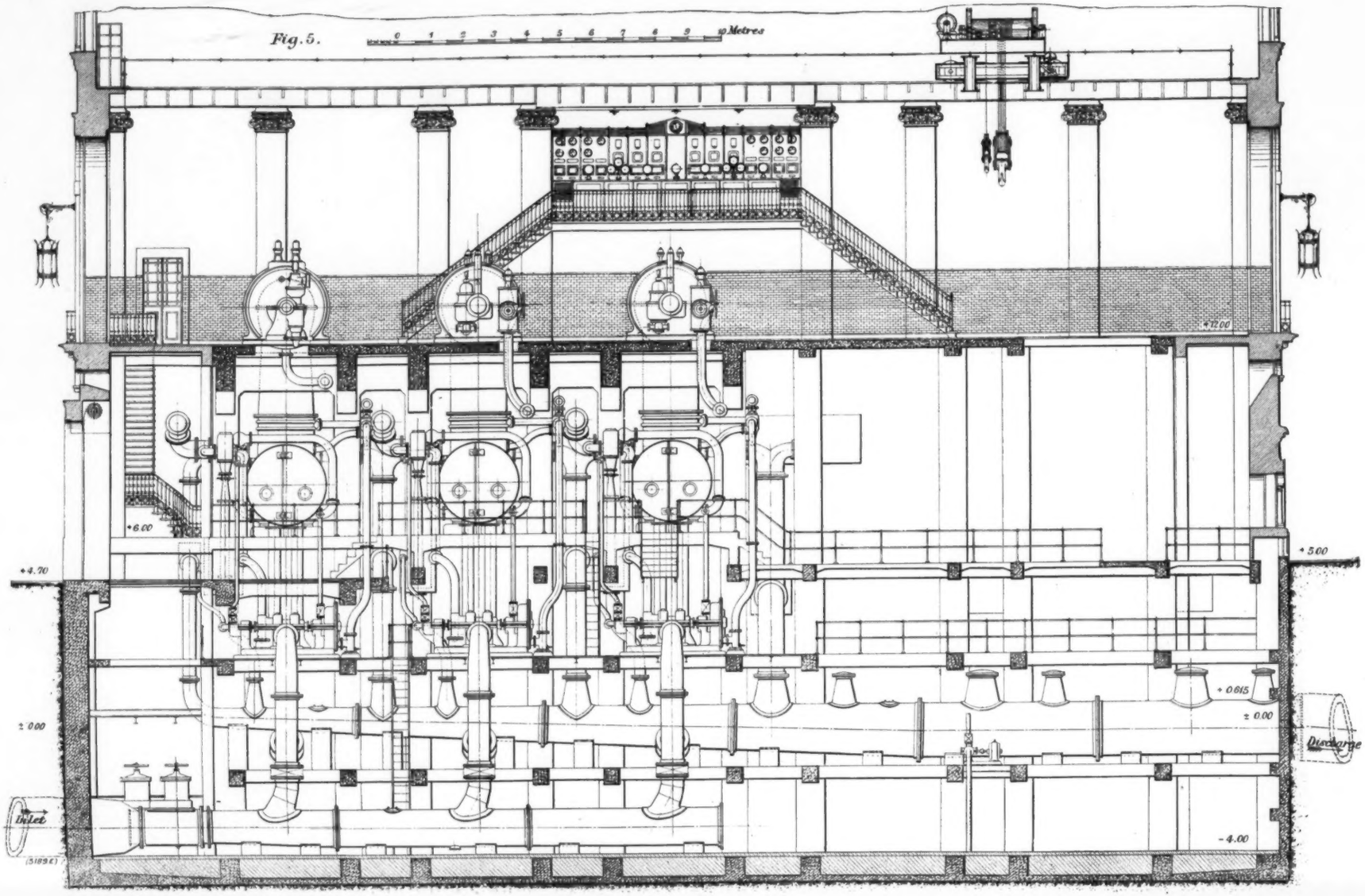
The turbine room measures about 62 ft. by 116 ft. in plan. The turbines are arranged on an upper floor with the condensers below, whilst a pit carried down to hard pan, and lined with concrete made watertight with asphalt, extends along the whole width of the turbine room in front of the line of condensers. A longitudinal section of this pit appears in Fig. 5.

There are two main inlet pipes for the condensing water, which enters the pipe pit on the left as indicated in Fig. 5. These pipes are each 14 sq. ft. in area, and are 377 ft. long, whilst the single discharge pipe which returns the water to the river has a cross section of 27.7 sq. ft. and is 476 ft. long. Inside the building the pipes are

ELECTRIC POWER SUPPLY AT BUENOS AIRES; THE PEDRO MENDOZA POWER STATION.

(*For Description, see Page 60.*)

Fig. 5. 0 1 2 3 4 5 6 7 8 9 10 Metres



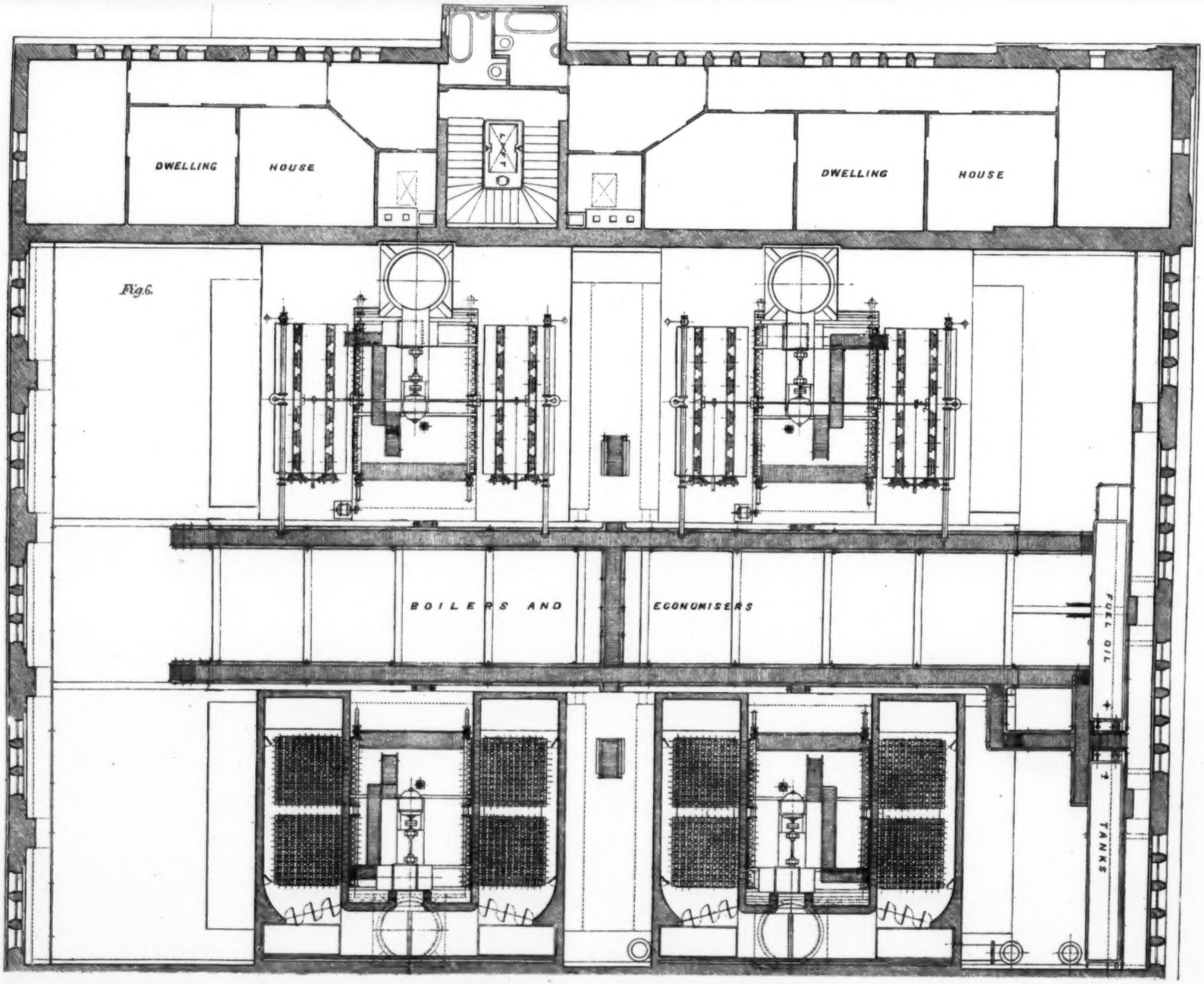

DWELLING
HOUSE
DWELLING
HOUSE
BOILERS AND
ECONOMISERS
FUEL OIL
TANKS

Fig 6.

of cast iron and cut-off valves are provided to both the inlet branches. The turbo-generators at present installed are three in number. Each is rated at 6,250 k.v.a., and supplies three-phase current at 6,600 to 7,000 volts, the periodicity being 50 cycles per second. Of these turbines, two were supplied by Messrs. Brown, Boveri and Co., and one by Messrs. Franco Tosi. Two more turbines, each rated at 12,500 k.v.a. are, now in course of erection, having been constructed by Messrs. Brown, Boveri and Co. We shall illustrate these in some detail in a future issue. An electric travelling crane, rated at 45 tons, is provided for handling heavy weights.

The Tosi turbine is of the disc and drum type. Its designed speed is 1,500 r.p.m. and it will give its full rated output of 5,000 k.w. with steam at a stop valve pressure of 13 atmospheres (gauge), and a stop valve temperature of 325 deg. C. By means of the bye-pass valves, this ouput can be raised by 25 per cent., and the generator, which was supplied by Messrs. Brown, Boveri and Co., will carry this overload safely for half an hour. The turbine casing is of cast iron split along a horizontal joint in the customary way. The rotor is built up in three main sections, and was carefully balanced after assembly. The packings are of the labyrinth type, the rotary portion of it being fitted to the shaft in the form of a sleeve, which allows of expansion, and checks the communication of heat to the shaft and consequent distortion if accidental rubbing should occur. The oil supply to the bearings is provided by a gear wheel pump, the usual cooler being fitted within the base plate casting. Both the ordinary and the bye-pass valves are under the control of the governor and are operated by an oil relay. The emergency or runaway governor is mounted direct on the turbine shaft, and comes into operation, cutting off steam completely, should the normal speed be exceeded by 10 per cent.

The Brown-Boveri units are similar in general construction to the larger 10,000 k.w. machines now being installed, and we will postpone our description of these to a later issue.

The switches are housed in a compartment at the end of the power house, and are controlled electrically from a switch board established in the turbine room as indicated. This has 20 outgoing leads and is of the cellular pattern, being supplied by Messrs. Brown, Boveri and Co. A battery of accumulators, with a capacity of 600 ampere hours, supplies the current for working the switches and acts as a reserve for the excitation of the generator magnets.

(To be continued).

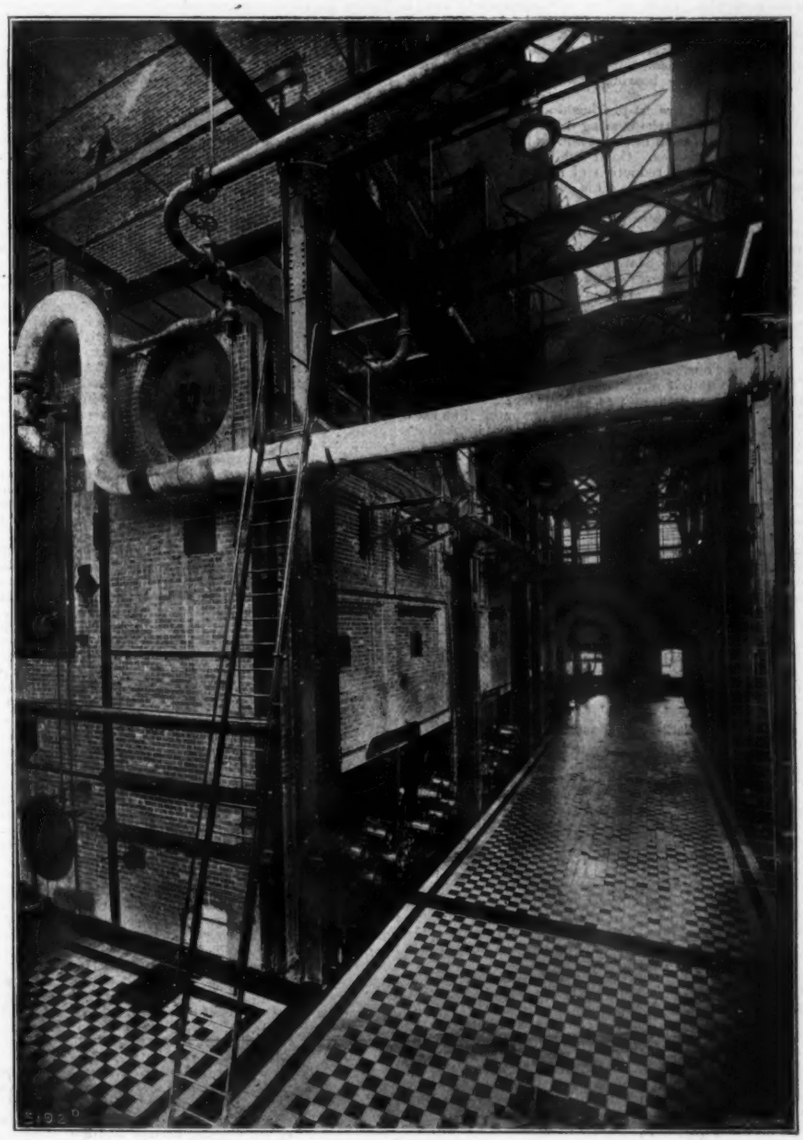


FIG. 7. BOILER HOUSE AT THE PEDRO MENDOZA POWER STATION.

NOTES ON OPERATION OF SUBMARINE DIESEL ENGINES.*

By Lieutenant F. C. SHERMAN, U.S.N., Member.

THE following notes have been made as the result of practical experience in operating submarine Diesel engines of the two-cycle Neurnberg type of New London Ship and Engine Company manufacture. They are particularly applicable to that engine, but it is felt that some of the ideas evolved may be adaptable to engines of other types when similar troubles have been experienced. No attempt is made to go into details of design or into the theory of Diesel engine construction as it is considered to be out of the province of this paper to treat of such technicalities. The notes made are the result of the writer's four years' experience in operating engines of the type mentioned above, and are made with the idea that they might be of some use to other operators of submarine Diesel engines. They are grouped into five divisions, as follows :—

I. Crank-case explosions.
II. Piston and cylinder troubles.
III. Wrist-pin troubles.
IV. Air-compressor troubles.
V. Auxiliaries.

In spite of the widespread reports of unreliability of submarine Diesel engines of the past few years, the writer has always maintained that every effort should be made to make the material operate satisfactorily before condemning it as unsatisfactory and unreliable. In many cases further investigation has shown that inexperienced personnel are to blame and not the long suffering and almost always blamed material. Acting under this assumption, every trouble experienced was thoroughly gone into and, if possible, a remedy for it evolved. The following notes are made from some of the troubles discovered and cured. It is hoped that they will be of some assistance to other Diesel engine operators perhaps wrestling with similar troubles.

I. CRANK-CASE EXPLOSIONS.

In the type of engine upon which this discussion is based, the crank case is totally enclosed and the oil from the lubricating system, after cooling the piston heads, is drained into the crank case, from which it runs into the settling tank and is used over again. The scavenger air for the working cylinders is compressed in a scavenger cylinder in tandem with the working cylinder and the piston is of the stepped type, the lower step working in the scavenger cylinder and compressing the scavenger air which is forced into a housing around the scavenger cylinder and above the crank case. The scavenger cylinder makes a joint between the crank case and the scavenger housing. Now in every case of crank case explosions it was found that there was a leak from the scavenger housing to the crank case. This joint was packed with soft packing and proved to be very difficult to keep tight, due to the scavenger cylinder holding-down bolts working loose from continual shock. But in every case of crank-case explosion, a leak of scavenger air to the crank case was found, and when it was corrected the explosions stopped. The permanent care taken following this discovery was to test the scavenger housing at frequent intervals for tightness with air pressure and to examine frequently the scavenger cylinder holding-down bolts and to keep them set up tight every time they came loose. These tests were made about once a month, as convenient with the boat's operation, and, following this care, practically all crank-case explosions and their destructive results were eliminated.

As to the theory of why this scavenger-air leak resulted in crank-case explosions it is impossible to give any very satisfactory explanation. The scavenger-air pressure is only about 7 lb. and its temperature from 140 deg. to 160 deg. F., although sometimes it would go up to 180 deg. F. It occurred to the writer that the lubricating oil draining into the crank case must be churned up considerably by the cranks revolving therein, which, together with the working heat of the engine, would cause a distillation of the volatile products† of the oil, and form an explosive mixture of vapour in the crank case, totally enclosed. This ignition point of this mixture must be close to or below the scavenger-air temperature, and consequently when the scavenger air leaked into the crank case the explosion resulted. Whether this is the true explanation or not, it is difficult to say, but it is certain that when there was no leak from scavenger housing to crank case no crank-case explosions occurred.

Another remedy adopted, not as a cure but to reduce the effect of a crank-case explosion, was to instal a vent to the crank case. The crank case is totally enclosed only for the purpose of retaining the oil used in the lubricating system and prevent its being splashed about in the engine room. The result was that when a crank-case explosion occurred the gas had no place to escape without wrecking something, blowing off the crank-case doors or housing. To prevent this, a 2½-in. pipe was led from one end of the crank-case housing and left entirely open. The end was taken to the scavenger suction intake for the purpose of furnishing a slight draught to the crank case and removing any gases collected there. This was not entirely necessary, however, as the main purpose of the pipe was to furnish an opening to the crank case to allow the expanding gases of the explosion to get out without blowing something out. As a result of this, if a crank-case

* Reprinted from the *Journal of the American Society of Naval Engineers.*

† This explanation seems doubtful. It is more probable that the explosive mixture present consists of oil bubbles filled with hot air.—EDITOR, J.A.S.N.E.

explosion occurred, in spite of our efforts to keep the scavenger housing tight, no damage resulted.

Another feature of the leak in the scavenger housing was found to be that the scavenger-housing temperature increased unduly, especially when running at higher powers. This undue rise of temperature probably resulted from slight burning of the oil vapour around the leak causing an increase of the temperature without, however, causing an explosion. A correction of the air leak always resulted in a decrease of scavenger-housing temperatures.

These leaks from the scavenger housing, it must be understood, were not sufficient to cause trouble from drop in scavenger-air pressure and would ordinarily not be expected to give any trouble. The effects on crank-case explosions and housing temperatures, however, were extremely annoying, as outlined above.

Closely allied with the crank case explosions, but of an entirely different nature, were scavenger-housing explosions. We found these to be due to two causes, namely, presence of a superfluity of oil in scavenger—housing and leaky or defective scavenger valves. If there was too much oil in the scavenger air, and the scavenger valve to the working cylinder remained open an instant too long, or leaked after it was closed, the compression temperature or flame from the working cylinder would be transmitted to the scavenger housing and set off the oil and vapour in that chamber, resulting in an explosion liable to wreck the housing, as relief valves fitted there were never efficient in quickly releasing the excessive pressure formed. The remedy for this form of explosion was to keep excessive oil out of the scavenger-housing through drains fitted at the bottom and to keep the scavenger valves to the working cylinders functioning properly. With these precautions very little further trouble was experienced with scavenger-housing explosions.

II. Piston and Cylinder Troubles.

Under this head are comprised cracked piston heads, cracked cylinders, cracked pistons and piston seizures. These troubles are almost all traceable to defective cooling of the piston head. On the particular type of engine in question, the pistons were cooled by lubricating oil forced up from the lubricating system through the connecting rod and wrist pin and then up through a pipe leading to the hollow piston head and thence down on the opposite side through a drain pipe to the crank case, whence it drains by gravity to the settling tanks.

All of the troubles enumerated above were directly attributable to defective cooling of the piston heads. The most frequent cause of this was the presence of salt water in the lubricating oil which remained in the piston head owing to the location of cooling-water inlet and outlet. Due to the temperature to which the oil was subjected, the water would quickly evaporate, leaving a salt deposit in the oil which was black in colour, giving the appearance of carbon. For a long time this deposit was thought to be carbon, on account of its colour, but an analysis showed it to be over 90 per cent. salt. This salt would form a black, gummy mass, and would soon collect in the piston heads and pipes leading to the piston heads and result in decreasing or blocking altogether the supply of cooling oil to the piston heads. Instantaneously the piston head would get hot and either crack or seize, or heat would travel to the cylinder or piston itself, resulting in cracking the cylinder with its cooling water outside or the piston seizing and cracking. Obviously the remedy for this is to keep salt water out of the oil. However, with an engine using salt water for its cylinder-cooling and oil-cooling medium, this is not as easy to do as it sounds ; but it can be done if proper care is exercised. On the vessel on which the writer served it was never completely accomplished until the circulating water pumps were removed from over the crank case where water leaking slightly past the plungers and stuffing boxes found its way into the crank case and there mixed with the oil. Another frequent source of trouble were the oil coolers, where the oil is cooled by circulating water before being again used in the engine system. The oil passed through nests of tubes surrounded by cooling water, and trouble was experienced in preventing tubes from pitting through and gaskets from leaking. Whereas the oil pressure when the engine was running was greater than the water pressure the leak would become effective when the engine was shut down and the lubricating-oil pumps stopped. Water would then leak in and cause trouble on the next run of the engine. Another source of leaks was from slight cracks in cylinders, sometimes quite imperceptible to the eye when cylinder was cold, but allowing slight leaks of cooling water to crank case when warm. All of these leaks wherever they may be, must be prevented to ensure proper cooling of piston heads and to prevent troubles ensuing from this source.

III. Wrist-pin Troubles.

Wrist-pin troubles, in brief, are due to insufficient lubrication, insufficient clearance, undue wear on bushing or pin, and heating resulting from hot piston or piston head.

The trouble due to insufficient lubrication causing hot wrist pins is in some cases traceable to the salt water in the oil, as explained above, and is caused by clogging of the oil passages as described. The remedy is the same as was there given. In other cases, however, it may be due to improper grooving of the wrist-pin bushing or bearing surface. This subject must be studied in connection with the approved forms of oil grooves for bearings, and steps taken to insure that the oil is being properly distributed on the wrist-pin bearing. As it has no special features, it is not gone into further here. On engines with forced-lubrication pumps operating from the main engine shaft, hot wrist pins frequently develop on first starting up an engine. This is probably caused by lack of lubricating oil in the wrist-pin bearings, the highest part of the system, when the engine is first turned over. This can be prevented on engines with an independent lubricating pump by starting up the auxiliary lubricating pump several minutes before attempting to turn over the main engines and running it long enough to ensure getting lubricating oil to all parts of the system. This should always be done before starting up, as frequently wrist pins will run hot and wipe in the few minutes before oil from the attached pumps can get to them.

Insufficient clearance on wrist-pin bushings sometimes results in not allowing sufficient lubricating oil to form a good film on the bearing and causes wiping or heating of the wrist pin. Good practice is to allow about .002 in. vertical clearance between the pin and bushing and about .006 to .008 clearance on the sides. This additional side clearance gives no more play in the bearing, as the pressure is always vertical, but gives the oil a better chance to circulate in the bearing and form the "oil film" or lubrication.

Undue wear on wrist-pin bushings results in loss of lubricating oil from the bearing due to leakage, and also in loss of compression in the cylinders from the dropping down of the pistons. Good lubrication in a forced-feed system requires reduction of all oil leaks to a minimum, especially where the oil is also required for cooling of piston heads. Every oil leak results in a loss of pressure and thus affects the quantity of oil going through the piston heads for cooling and also the effectiveness of the lubrication through reduction of the oil pressure on each bearing. Consequently anything which can be done to prevent undue wear on the wrist-pin bushings is important. In addition, loss of compression in the cylinders causes inefficient combustion of the fuel, reducing the economy of the engine, and necessitates frequent overhaul and insertion of liners under connecting rods to increase compression or frequent renewal of wrist-pin bushings. This reduces the availability of the engine and is extremely undesirable. This undue wear on bushings may be due to insufficient lubrication on starting up, as described above, and is remedied as there given. However, it may be caused by improperly made wrist pins or bushings. The bushings should be of phosphor bronze, of as tough and durable a composition as possible. The wrist pins are of steel, hardened on their wearing surface by either the bone or cyanide processes. The wrist pins furnished us originally were bored out from one end only and that end plugged with a threaded brass plug. We found that the pins would take a more uniform heat and better hardening if the pins before hardening were bored clear through and both ends plugged with the threaded brass plugs. This was a slightly more costly process, but resulted in much better pins, and is recommended for all wrist pins for Diesel engines. These steps are about all that can be taken to reduce undue wear on wrist pins and bushings.

Heating of wrist pins from hot pistons and piston heads is caused by heat transference from the above parts and can only be remedied by correcting the cause as discussed under II above.

IV. Air-Compressor Troubles.

Diesel engine air-compressor troubles comprise valve trouble, cooler leaks and explosions. They are due to the high temperatures created when the air is compressed in two or more stages from atmospheric pressure to approximately 1,000 lb. per square inch. In the type of engine mentioned at the beginning of this paper, the compressor was designed to take its suction from the scavenger-air housing, and it was then compressed in two stages in tandem to 800 lb. to 1,000 lb. per square inch. This air was cooled from each stage in a cooler consisting of nests of small, straight tubes around which circulated cooling water. The air from the second-stage cooler passes to the spray-air bottle which acts as a reservoir on the way to the spray-air line of the engine. It will be seen that when the two-stage air compressor takes its suction from the scavenger housing containing air at 7 lb. pressure (above atmosphere) it virtually makes a three-stage compression. On our engine, however, there was always so much oil in the scavenger housing that it was considered dangerous to compress air containing so much oil and subject it to the temperatures reached, and in practice it gave considerable trouble. So the suction to the scavenger housing was disconnected and a suction direct to the atmosphere substituted which gave a straight two-stage compression from atmospheric pressure to 1000 lb. per square inch. This worked much more satisfactorily as regards presence of oily vapour in the compressed air and occurrence of cooler explosions.

A common practice in Diesel engine design seems to be to have a restriction in the spray-air line between the reservoir and the engine. The only object of this that I have been able to discover is to enable a higher pressure to be carried in the reservoir than is needed on the spray-air system, so as to build up a reserve for starting after the engine has been shut down. It this is its purpose it never was successful for us, and only resulted in reducing the amount of spray air we were able to get through to the fuel valves. Furthermore, it would frequently clog up and catch dirt and oil to further reduce the opening, so that in general it was more of a nuisance than anything else. Acting on this belief, the restriction on the spray air was removed entirely and much better results in every way were obtained. Whereas before poor fuel combustion had been obtained when carrying 800 lb. to 900 lb. pressure on the spray air, after removing the restriction perfect combustion was obtained with as low as 550 lb. to 600 lb. pressure on the spray air. Needless to say, the restriction was never again replaced. This may not be of any advantage on other engines, as the type of fuel valve and size of spray nozzle may not permit of any difference, but for us it worked wonderfully well, giving better fuel pulverisation and relieving the air compressor enormously of extra load and correspondingly higher temperatures due to the higher pressure required with the restriction in place.

Another point in regard to air-compressor trouble is cylinder lubrication. The principal danger of this is too much lubrication, allowing oil to be carried into the compressed air and causing high temperatures or explosions from burning or combustion of the oil vapour. The best practice is to eliminate direct cylinder lubrication entirely and depend on the moisture and oily vapour in the engine-room atmosphere to furnish sufficient lubrication. In practice this worked very well for us, and we had no trouble from lubrication while using no oil whatsoever directly on the air compressors.

The principal valve trouble which we experienced was due to the valve springs losing their temper after a few hours' running due to the high temperatures of the uncooled air to which they were subjected. The second-stage suction valve was the principal source of trouble, and when its spring gave out it would leak, allowing second-stage pressure to back up in the first-stage receiver and increase the work on the first stage and, in general raise hob. Another source of valve trouble was the gradual collection of carbon deposits on the valve seats due to the presence of oil in the air and causing the valves to leak as described above. Cutting off the oil used for cylinder lubrication helped both the above troubles. But the greatest assistance to correct these faults was a water cup installed on the first-stage air suction and set to feed a small quantity of fresh water into the compressor with the air. This water cup was simply a large oil cup arranged for drop feed, filled with fresh water instead of oil. A fairly rapid feed was set on it, about two to four drops per second, and this water was dropped through the top of the air-suction pipe and drawn into the compressor with the air. The action of this fresh water was found to be as follows : The water helped to lubricate the valves and cylinder walls and prevented the deposit of carbon. The high temperature almost immediately turned it into steam, absorbing some of the heat without rise of temperature in the form of latent heat, and thus keeping down the temperatures developed due to compression. In addition the steam kept the carbon from collecting and gumming up the valves, and the reduced temperatures resulting prevented the springs from losing their temper. This fresh-water cup was a fine thing, and I strongly advise other Diesel engine operators to try it on their air compressors.

Cooler leaks were probably caused by high temperatures and possibly some electrolytic action on the tubes. The installation of the water cups kept down the temperatures and also kept carbon and oil from collecting in the coolers and restricting the heat transference. To prevent electrolytic action the outside of the copper tubes was tinned and small zincs were placed in the cooler. These precautions eliminated almost all of our air-compressor troubles. In addition all clearances were kept down to a minimum, about 1-64 in. on both stages.

V. Auxiliaries.

Under this head is included the lubricating-oil pumps, the fuel-oil pumps compriaing supply and measuring pumps, and the circulating-water pumps. The principal troubles experienced with auxiliaries were with those geared to the main shaft. These pumps were the reciprocating type and comprised a fuel-feed pump, a lubricating-oil pump and a circulating-water pump, all driven by one large crosshead operated by a crank shaft geared to the main shaft. The first trouble experienced was with the fuel-oil supply pump, which leaked, in spite of efforts to keep it tight, a small amount of fuel oil into the crank case. After mixing with the lubricating oil this caused rapid deterioration of the lubricating oil for lubricating purposes, as well as scavenger and crank-case explosions from its low flash point and volatility. To obviate this trouble the fuel-pump was removed and a gravity fuel feed substituted, the gravity fuel tank being supplied by a small rotary pump, motor driven, secured to the bulkhead. This removed all possibility of getting fuel oil into the lubricating oil and prevented recurrence of its evils. The lubricating oil and circulating-water pumps were the next to give trouble. They were high-speed reciprocating pumps, and it was almost impossible to keep salt water from leaking from the circulating-water pump and finding its way to the crank case and, ultimately mixing with the lubricating oil, causing all the troubles enumerated under Division II. In addition, mechanical difficulties with these reciprocating pumps caused by momentary high pressures when the pump became air bound or through defective valve action, resulted in frequent stripping of gears and breaking of pump crank shafts. These breakdowns finally became so frequent that independent motor-driven rotary-type pumps were installed for both lubricating oil and circulating water. The reciprocating-pump connecting rods was disconnected and lashed clear, and the salt water connections were blank flanged to prevent any possibility of salt water leaks, and these pumps were not used but were kept available for connecting up in case of failure of the independent pumps. In nearly two years of operating they were never needed to be used, the independent pumps operating entirely satisfactorily. As a result of this, we became strong advocates of independent auxiliaries for submarine Diesel engines, more especially on account of the power of the main storage batteries being always available and the replenishment of the power being feasible while the main engines were running by floating the main motors on the batteries and pulling enough current to compensate for that used by the auxiliaries.

The fuel-measuring pumps were of the plunger type, driven by an eccentric off the main shaft. The regula-

tion was by means of the suction valves being held open for a part of the discharge stroke to control the quantity of fuel oil discharged to the fuel valves. This regulation was made by the operator through a hand wheel controlling the rocker arm operating the valves. These pumps gave very little trouble except from wear, and it was necessary to renew the plungers and barrels about every six months to a year on this account. The plungers were required to fit the barrels very closely on account of loss of pressure through leakage past the plungers. Aside from this amount of wear these pumps gave no trouble, and the method of control was entirely satisfactory.

It may be only just to conclude these remarks by a statement of the results obtained when paying attention to the details enumerated above. Two engines of the two-cycle type mentioned were operated for a period of nearly two years after the above methods were put into effect, and during this time no major casualty of any kind was experienced. By major casualty is meant one requiring the services of a Navy Yard or tender to repair. No minor casualty requiring more than a few minutes' stop to repair occurred, and no cracked piston heads and but one cracked cylinder were experienced during this time. In fact the reliability of these engines was considered excellent by the operating force, and the cruising radius was regarded as only limited by the fuel oil storage capacity. If Diesel engines will fulfil this requirement no more can be expected of them. In conclusion, if these notes are of any assistance to other operators of submarine Diesel engines their purpose will have been fulfilled.

THE TRUMBLE REFINING PROCESS.*

By N. W. THOMPSON, †San Francisco, Cal., Non-member.

THE first step in the refining of oils is to obtain the different fractions or distillates of the crude oil. Some of these are ready marketable products and others need treatment. To obtain these distillates it is necessary to distil or boil them over in a still and separate them according to boiling points.

Old Method of obtaining Distillates.—The old method was to fill a cylindrical still with the crude oil and boil off the lighter distillates, then the next heavier, and so on. After being condensed these distillates were run through a steam still and the still kept to a certain temperature until all of the lighter fraction or first cut was obtained, then the temperature was raised for the next fraction, and so on.

A large number of the refineries at the present time continue this system, and others put a number of crude stills in series and run them continuously; that is, the residuum or bottoms of the first still run to the second still where they are heated to a higher temperature and so on to the last still, from which the residuum flows to a cooler and then to the tank. This residuum is generally fuel oil.

In these stills there is a large volume of oil over the fires and also an expensive installation to build and maintain. There can be no seams in the bottom of the stills necessitating very large plates, and it is necessary to have perforated steam pipes in the bottoms to agitate the oil so as to keep the bottoms from burning, etc.

Large surfaces are necessary when the heating is done in this way. There is low heat transfer on account of slow velocities and the low specific heat of the liquid, and about one-third of the surface of the still cannot be heated and must be highly insulated to avoid excessive radiation. However, the radiation losses are considerable even in the best settings.

Trumble Distilling Apparatus.—The Trumble distilling apparatus is quite a departure from that used in the method described and has proved very successful in the plants where it has been installed. The principal parts of the apparatus are shown in Figs. 1, 2 and 3.

In Fig. 1 is shown a Trumble evaporator, to which in this case is connected an evaporator column. The evaporator consists of a closed cylindrical metal shell, vertically disposed, to which heat is applied from the outside in any convenient manner, as for example, by flue gases or by vapours from another evaporator.

Inside the evaporating chamber is arranged a central vertical pipe having umbrella-shaped devices attached thereto at intervals which are called "spreader hoods," so that oil fed to the apex of these hoods will flow down over their sides in a thin film after the analogy of rain flowing down the outside of an umbrella. The lower edges of these hoods are at a little distance from the sides of the wall of the evaporating chamber, and in operation the oil flows down and over the hood and strikes against the interior wall of the evaporating chamber and flows down the wall in a thin continuous film.

In case any of the oil should not strike against the wall in the evaporating chamber, but should drop off the edge of the hood and fall vertically; or in case there should be a tendency to bubbling or foaming on the wall of the evaporating chamber whereby a portion of the oil may be thrown back toward the centre of the evaporating chamber, such oil will be caught by the next spreader hood and will flow down the surface thereof, thereby insuring an ultimate spreading of the oil on the wall of the evaporating chamber.

The oil to be operated on is fed through a supply pipe to the top of the evaporating chamber and discharges downward on the apex of the uppermost hood. The oil then flows down this hood in a thin stream and is delivered against the interior wall of the evaporating chamber as herein above described.

The centrally arranged vapour take-off pipe in the evaporating chamber, to which the spreader hoods are attached, is provided with perforations underneath each of the hoods, and through these perforations the vapours pass from the evaporating chamber into the vapour take-off pipe. Located in this vapour take-off pipe are lateral branch pipes, and these branches extend through the wall of the evaporating chamber to the outside of the apparatus.

Fig. 2 shows the construction of the separator. This is a re-run still for distillates from bottoms of dephlegmators, or from any other source, if these need fractionating. The distillate flows into compartment (1) over a number of pipes through which a heating medium is passed, either residuum or vapours as the case may be, and then passes through an opening at end of compartment (1) into compartment (2) and back through compartment (3) and so on, leaving at end of compartment (6). The vapours evolved in compartments (1), (2) and (3) pass through openings into vapour compartment *B* and out through opening b_1 to condenser, &c.

The manifolds on the ends of the separators are provided with covers having stuffing boxes through which valves are operated to regulate the flow through tubes in each compartment, thereby controlling the heat in these compartments.

Description of Plant employing Trumble System.—The illustrations, Figs. 3 to 6 inclusive, are from photographs taken during the construction of a plant employing the Trumble system. Fig. 3 gives a general view. In the foreground, at the left, is the pipe heater, and located in the brickstack at the left is the evaporator. In the distance are the dephlegmators, in the foreground the separators, and the vertical condensers for the vapours from the separators. Under the arches are the coolers for the distillates. The pipe lines in the trench are the distillate lines from the condensers and coolers carrying the cooled products to the receiving boxes. The arrangement of these receiving boxes is shown in Fig. 4. Behind the boxes are dewatering traps for separating the water from the distillates. Fig. 5 shows the dephlegmators with the heat exchangers underneath. Fig. 6 shows the operating valves for the distillates from the dephlegmators. These valves as well as all operating valves are handled from one platform.

All plants are designed to meet the conditions under which they are to be used, but they are very flexible and are able to take care of a very wide range of conditions by controlling the heat of the furnace and the velocity of the oil which runs through it. It will be impossible to go into the many different arrangements of plant design, but the following will make clear the running of a typical and successful plant.

Flow of Oil through Plant.—The flow of the crude oil through the plant is indicated by the flow sheet in Fig. 7. The oil enters through a 6-in. line and is used as a cooling medium in the six coolers shown. These coolers are of the horizontal tubular type, 30 in. in diameter, with sixty-two 2-in. by 18-ft. tubes. The oil enters at the bottom and passes through the tubes, making four passes, and comes out at the top and goes into a header through which it passes into the four heat exchangers or coolers for the residuum.

These heat exchangers are 48 in. in diameter and have 178 2-in. by 18 ft. tubes. The crude oil enters the first heat exchanger at the bottom and passes through the

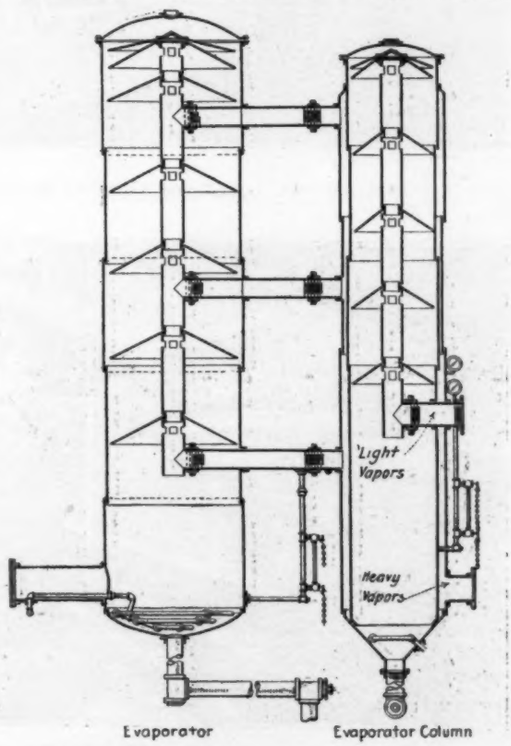


FIG. 1. EVAPORATOR AND EVAPORATOR COLUMN.

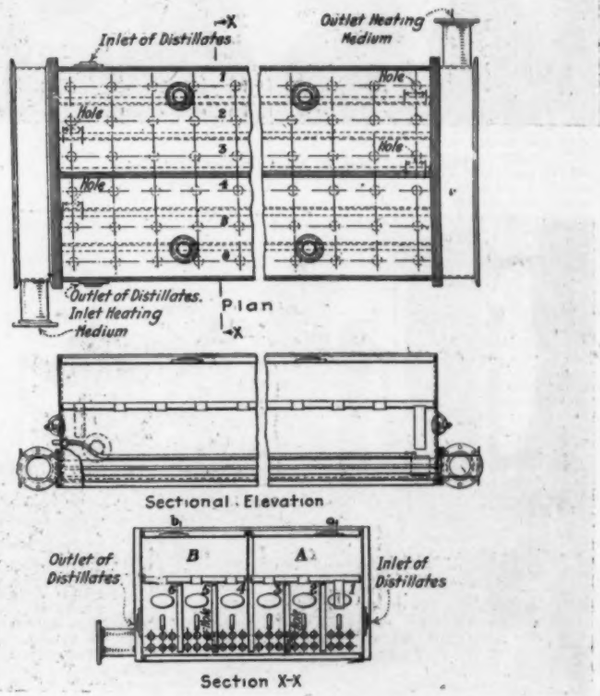


FIG. 2. SEPARATOR.

* Paper presented at the Annual Meeting, December, 1917, of *The American Society of Mechanical Engineers*, 29, West 39th Street, New York. Contributed by the San Francisco Section.

† Engineer Simplex Refining Company, San Francisco, Cal.

tubes, making six passes, and out at the top into the bottom of the next exchanger, and so on, to the heater pipes where it is split in two, each half passing in series through seventy-two 18½-ft. lengths of 4-in. pipe, flowing back and forth and upward at all times, and then into the top of the evaporator, where it flows down the sides in a thin film.

The oil in passing through the heater pipes and evaporator is heated by the flue gases. The vapours evolved are separated in the evaporator and taken care of later. The oil is maintained at a constant level in the bottom of the evaporator and runs out of the bottom of it as residuum. A perforated steam coil is placed in the bottom of the evaporator under the liquid and superheated steam is passed through it in order to drive off any of the lighter distillates which may drop back from the vapours. However, very little steam is necessary in this case as the heat losses are supplied by the flue gases.

After leaving the evaporator the residuum is used as a heating medium for re-distilling the distillates passing through separators, and then flows through the heat exchangers counter-current to the crude oil. The residuum enters the first heat exchanger at the top and makes two passes around the tubes and out at the bottom, then into top of the second exchanger, and so on through the five heat exchangers and through a standpipe, which is vented and which controls the head of residuum in the bottom of the evaporator, and then to the storage-tanks.

Having followed the course of the crude oil through the apparatus, showing the separation of it into vapours and residuum, it remains to dispose of the vapours shown on the flow chart in Fig. 8. The vapours from the central vapour column of the evaporator are taken out through a shell and connected into a header. The vapours pass from this header through an oil catcher similar to a steam separator, the condensate passing out of the bottom of it into the bottom of the evaporator. They then pass through six large dephlegmators in series, flowing into the bottom of each and out at the top, In each dephlegmator a partial condensing of the vapour takes place, thus forming a liquid at the bottom of that particular dephlegmator. From some of the dephlegmators this condensed liquid is a ready product—from others it is just between two different products.

A system of water circulation is used as a cooling medium for the vapours from the dephlegmators and separators. The vapours are cooled in vertical tubular condensers and about 20 barrels of water are required per barrel of distillate cooled. Superheated steam is used in the bottom of the evaporators, separators and dephlegmators as an agitator to relieve the lower boiling-point fractions from the bottoms. About 30 lb. of steam are used to each barrel of distillate produced.

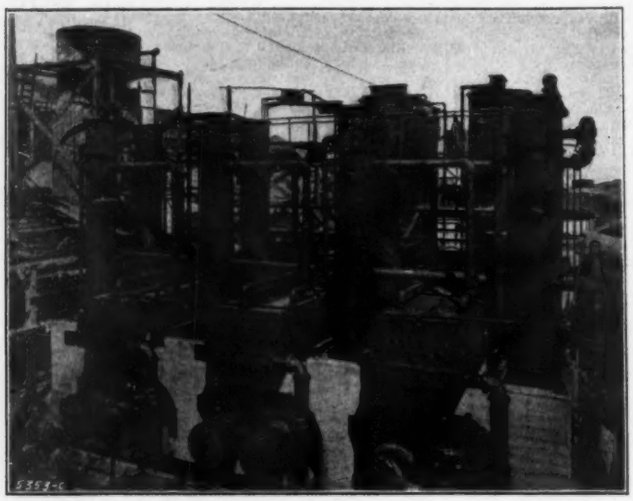


FIG. 3. GENERAL ARRANGEMENT OF PLANT.

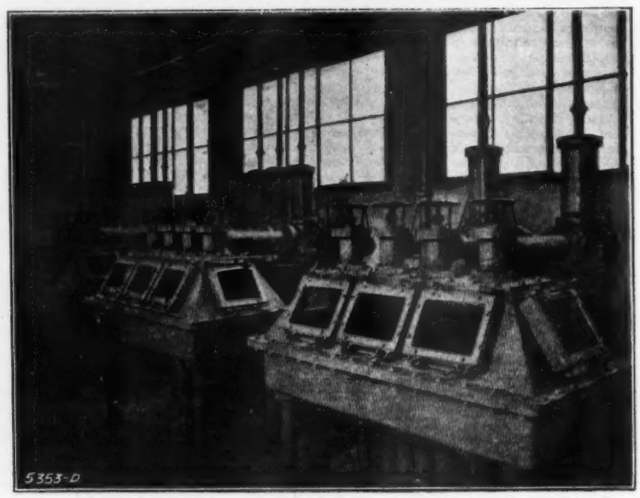


FIG. 4. ARRANGEMENT OF RECEIVING BOXES.

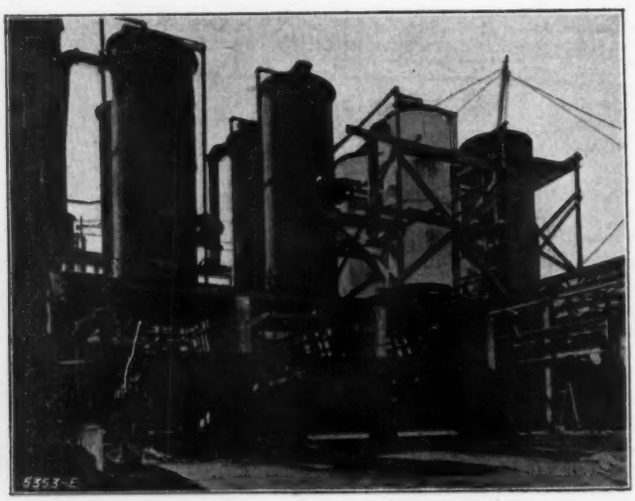


FIG. 5. DEPHLEGMATORS WITH HEAT EXCHANGERS UNDERNEATH.

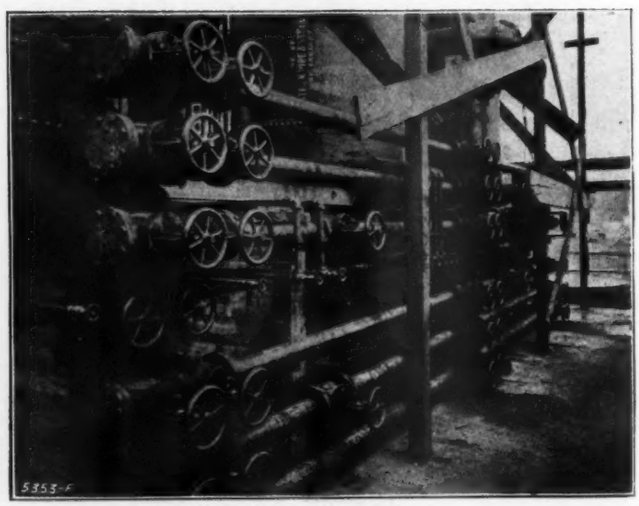


FIG. 6. OPERATING VALVES FOR DISTILLATES FROM DEPHLEGMATORS.

After leaving the evaporator the residuum is used as a heating medium for re-distilling the distillates passing through separators, and then flows through the heat exchangers counter-current to the crude oil. The residuum enters the first heat exchanger at the top and makes two passes around the tubes and out at the bottom, then into top of the second exchanger, and so on through the five heat exchangers and through a standpipe, which is vented and which controls the head of residuum in the bottom of the evaporator, and then to the storage-tanks.

Having followed the course of the crude oil through the apparatus, showing the separation of it into vapours and residuum, it remains to dispose of the vapours shown on the flow chart in Fig. 8. The vapours from the central vapour column of the evaporator are taken out through a shell and connected into a header. The vapours pass from this header through an oil catcher similar to a steam separator, the condensate passing out of the bottom of it into the bottom of the evaporator. They

Installations of the System.—The company for whom this plant was installed has two Trumble plants in operation — the No. 2 plant above, and the No. 1 plant. The No. 1 plant differs from the No. 2 plant in that an evaporator tube is used with the evaporator and two fractions of vapours are given off. These vapours are used as a heating medium in separators and are then condensed and run back to the separators and fractionated in same. When this plant was first started the fractionating of the distillates was not close enough for ready products and some of the products had to be re-run. After a few experiments small dephlegmators were installed on the vapour lines from the separators, and from that time on there has been no occasion to re-run any of the distillates.

With these two Trumble plants in operation continuously for eight months, the company has averaged a run of 16,000 barrels of crude oil per day of 24 hours through both plants, 30 per cent. of this crude oil being vaporised and fractionated into readily marketable distillate products. During this time 1.1 per cent. of the total amount of crude oil run was used as fuel to do this work and the refining losses were 0.75 per cent. of the total amount of crude oil run.

Five men are required for operating the two plants per shift, *i.e.*, one head stillman over both plants, one stillman at each plant, one fireman for both plants, and one receiving-house man for both plants.

The Trumble system has been successful from the very first installation. The Santa Fé Railroad Company has used the system in the Midway oil fields with success. The first expansion or evaporating chamber used for this installation was made by joining two old boilers together, end to end, while the rest of the apparatus was either made in the shops of the company, in the field or was picked up on the property. This plant, composed of remnants, so to speak, worked from the very start and uninterruptedly for several years—in fact, up to the time the Santa Fé made a trade of the oil on their grounds for a heavier oil delivered at Mojave, a division point on their main line.

There was no demand for perfect separation of the distillates at this plant, but a rough refining was done. Two products were made from the tops, one being 53 deg., while the other was from that point down to about stove distillate. The 53-deg. cut was water-white and was generally used in automobile engines by the Santa Fé on their Midway property. The distillates produced sold at profitable figures and were much sought after.

One of the main benefits claimed to be secured by the use of this form of still is that the oil while being heated or when giving off its vapours is never exposed to any action tending to "crack" or break down the molecular structure. As proof of this, it is particularly pointed out that one can never detect any odour of marsh gas around a plant of this kind, which is so apparent in all other forms of oil-distilling plants.

This absence of "cracking" and resultant freeing of carbon led up to the adoption of the process in making asphaltum for all purposes, but more especially that used in road work. The first plant of this kind was installed for the John R. Ott Company and produced oils for road work which secured much better prices than other refineries were able to secure, for the reason that the oils had greater viscosity, toughness and lasting qualities owing to the complete absence of free carbon, which, as every engineer knows, causes the asphaltum to break, in the markets on account of their ability to produce any quantity of any grade having the same penetration, a thing impossible to obtain where the individual still and batch method is followed. It is only necessary with the Trumble process to raise and maintain the required degree of temperature, and the product therefrom will be absolutely uniform, no matter whether it is one hundred tons or one hundred thousand tons. Again, when a different penetration is required, the flow of oil may be either hastened or retarded, and the desired

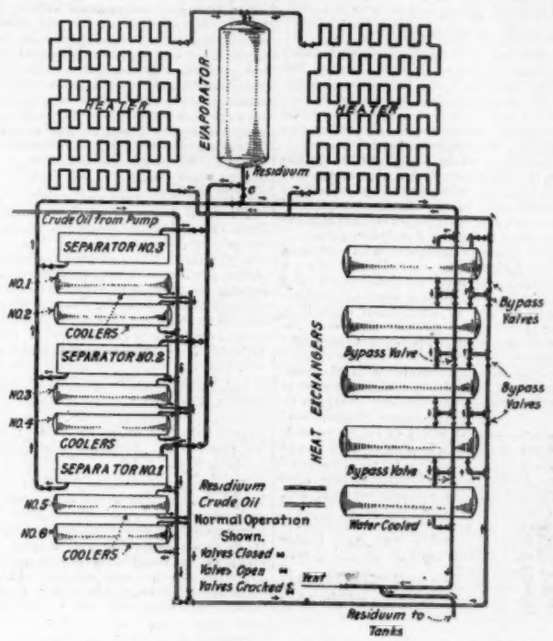


FIG. 7. CRUDE OIL AND RESIDUUM SYSTEM.

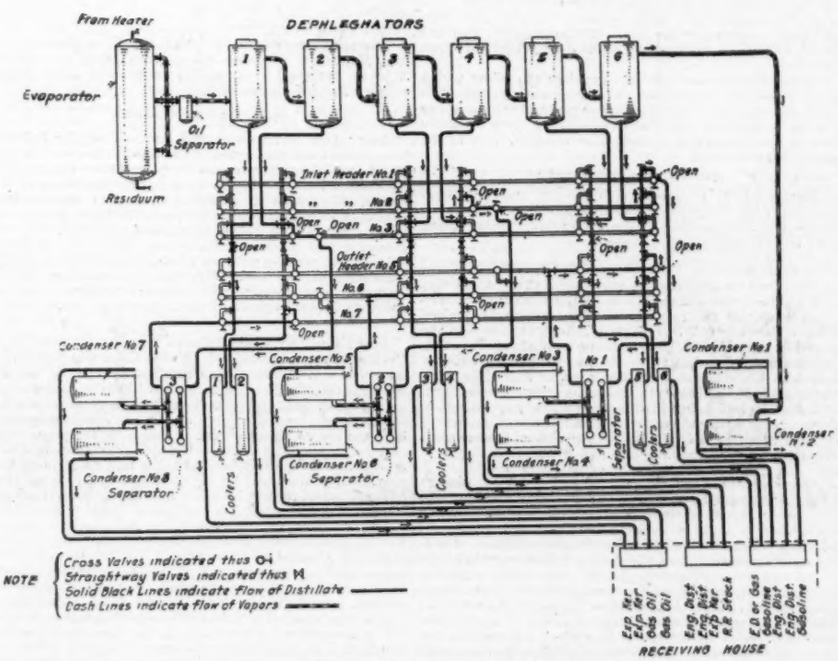


FIG. 8. VAPOUR AND DISTILLATE SYSTEM.

or what is commonly termed, to "short." The Ott Company was afterwards disposed of to a company owning wells producing heavy oils in the Santa Maria fields, and a larger plant was erected there; and it is quite safe to say that a large percentage of the roadways of California are now either coated with or contain asphaltum treated in this plant.

Another instance of the successful use of this system for manufacturing asphaltum is the Warner Quinlay Asphalt Company, which has its refinery at Warner, New Jersey. This plant has been making a high-grade asphaltum for a number of years by this process with uninterrupted success. Their goods have found favour

product derived. The same results are secured by regulation of fires.

For instance, a certain number of tons of a certain grade of asphaltum may be called for. The stillman regulates flow of oil or fires to produce the desired results. When the required amount has been produced he simply makes his changes in oil flow or fire regulation to produce the asphaltum of any other desired specification. No cooling down of stills or cleaning out is required.

The oil in passing through the entire apparatus is not subjected to the direct heat for any great period of time and at no time is it in a quiescent condition, which generally tends to burn or coke it, thus leaving coke on the iron, which, if not removed, soon causes the burning out of the still.

Economy of the System.—At the present time the necessity for conserving the fuel oil and labour around an oil refinery is imperative. The whole subject is a matter of heat units and their proper conservation.

In the Trumble system the products to be re-run in the separators are condensed but not cooled, thereby saving heat. The oil is in a very thin film on the shell of the evaporator and is being heated in its downward flow. The vapours being evolved have a free relief and have no opportunity of dropping back into the residuum.

There is considerable work for the mechanical engineer in the conservation of heat units around an oil refinery and in most all branches of the oil industry. There are large refineries operating to-day and using four to five hundred per cent. more fuel than is necessary to do the work. It is possible to save, by proper distribution of the heat available around the oil refineries in the United States, at least 2 per cent. of the total crude oil put through these refineries. There are large oil refineries operating to-day that are using as fuel 4 per cent. of the crude oil run through them to do less work than the plant described is doing on 1.1 per cent. of the crude oil run through as fuel, and the losses due to non-condensable gases, &c., are 2 per cent. against 0.75 per cent.

FERRO-CONCRETE SHIPBUILDING.—A company has been formed in Denmark for carrying on the Alfsen method of ferro-concrete shipbuilding. Suitable sites have been secured on the Limfjord, at Norre Sundby, and close to the Co-operative Cement Works. The undertaking will be started on a fairly comprehensive scale and under satisfactory auspices, and it is the intention to build not only lighters but sea-going vessels up to 1,000 tons dead weight. Mr. Alfsen, the inventor of this novel method of launching, is a member of the board. The Alfsen method will also be adopted by a company, with a capital of 55,000*l.*, which is constructing a yard at Arendal, on Tromöen, specially laid out for the building of ferro-concrete vessels of 1,000 tons dead weight. Also in Sweden a company has been formed for the purpose of building ferro-concrete vessels on a large scale. The original Alfsen yard in Norway, the Porsgrund Cement Works, is about to increase its capital, by some 30,000*l.*

GERMAN INDUSTRIAL ACTIVITY.—The movement for expansion and combines within the German industry goes on without any abatement, and it looks as if not a few industrial concerns had adopted the view of Bernhardi and others in connection with States, that only large undertakings have a real right to existence. The German Luxemburg Mining Company and Iron Works have purchased the rolling mills for thin plates of Weber, at Brandenburg an der Havel. The Mannesmann Tube Works have purchased nearly all the shares of the Humboldt Coal Mining Company, which owns extensive fields in Bohemia: the purchase is no doubt intended for the coal requirements of their Austrian company which has a capital of £1,100,100, and which controls two works, respectively at Komotow and Schönbrunn. The Netker Rhine Mining Company is about to increase its funds for the purpose of pushing ahead with the working of the coalfields of the three concerns, Grossherzog von Baden, Süddeutschland and Ernst Moritz Arndt. The increase of capital takes the shape of a payment of 1,000 marks per portion (Kux) which means a sum of 3,000,000 marks. Production from the first mentioned mine has recently commenced, but there is a shortage of labour. In view of the difficulties in the way of obtaining an adequate selling organisation of their own the four works forming the Upper Silesian Steel Union have made an arrangement with the German Iron Commune Company (Deutscher Eisenhandel) and so as to be able to exercise some control, the Upper Silesian Steel Union has acquired 6,000,000 marks shares in the Deutscher Eisenhandel and now have a representative on the board. The Electric Power station at Alt Würtemberg has increased its capital from 2,000,000 marks to 4,500,000 marks, which additional capital has been taken over by the Lahmeyer Electricity Company in Frankfort. At the instance of the Bavarian Minister for the Interior an important move is being made for the further exploitation of the Bavarian water power, more especially that of the Upper Inn and the Isar from Munich to Moosburg. A co-operation between the Bavarian Water Power Union, a number of leading Bavarian Boards, the industries more directly concerned, the Griesheim Elektron Chemical Works, Frankfort, the Schuckert Electrical Company of Nüremberg, some Berlin Banks and financiers, &c. The Fried Krupp undertaking of Essen and the Bavarian Friedrich Krupp Company are also interested in the venture, as is the city of Munich as far as the exploitation of the Isar is concerned. The Bavarian State authorities have promised to grant every facility. The chemical works of von Gleyden, at Radebene near Dresden, are increasing their capital from 7,000,000 marks to 10,000,000 marks: the old shareholders have the premier right to issue at a price of 160 per cent. The company paid 16 per cent. for 1916, and the capital has been increased twice before, each time by 1,000,000 marks. Considerable activity prevails within the wagon industry; the Nerdingen Waggon Company has decided to increase its capital from 2,500,000 marks to 4,000,000 marks: the dividend for last year will probably again be fixed at 15 per cent. Another amalgamation between a Silesian and a Westphalian concern has taken place, the Linke Hoffmann Works at Breslau having combined with the Herbrand Company, near Cologne. The capital of the former company, which at present amounted to 16,575,000 marks will be increased in consequence.

THE CREEP OF RAILS.*

I. RAIL-CREEP.

By FRANK REEVES, *M.Inst.C.E.*

IT occurred to the author some years ago that light might be thrown on the cause of rail-creep by making a few simple experiments.

He began by passing a wooden wheel several times in succession, in one direction, over a planed white-pine lath resting on a hardwood bench, and found to his surprise the lath had moved bodily about 2 mm. in the direction of travel, the total amount of the latter having been about 14 m. Up to that time the author, in common with many other railway engineers, had held the opinion that creep was probably in the main due to temperature-changes, assisted by the movement of trains.

He, therefore, made a further series of experiments: and although he has not had time or opportunity to deduce, in a thorough and final manner, the laws which govern creep, he has come to certain conclusions which, as current literature on the subject almost wholly demonstrates that the cause of creep is not understood, he thinks it desirable to put on record.

The results of the further experiments, which were made not only with pine laths, but also with flat iron bars on side and on edge, and with a strip of indiarubber, are given in a Table, and the conditions under which they were made are explained in detail.

The broad conclusions at which the author arrived were:—

1. Creep of rails is due primarily to deformation of the rail as the wheel passes over it. It may be likened to the movement of dough when rolled under a rolling pin.

2. The more violent the deformation, the greater the creep. That is to say, that creep is increased by (*a*) increasing the wheel-load: (*b*) diminishing the rigidity of the rail, by either reducing its section or using a weaker material.

He then sets out in detail the evidence in support of these conclusions, and proceeds to discuss the influences of various factors as follows:—

Weight of Wheel.—This appears to be the most powerful factor affecting the amount of creep.

Rigidity of Lath.—In every case the creep was much greater with the lath on the flat than with the same lath on edge.

Continuous versus Intermittent Support.—With the pine lath, the creep was always greater—from twice to four times—when the lath was supported on sleepers resting on the naked bench. The effect was heightened when the lath was on the flat as compared with on edge, which again bears out the theory that creep is an effect of deformation in the rail.

Yielding of the Support.—From the experiments with the pine lath the general conclusion is that interposing a strip of rubber between the bench and the lath made little difference, even reducing the creep, if anything (except in one case with a heavy wheel on a lath on the flat). It would appear that with a light wheel-load and a rigid rail the yield of the road-bed has little effect, and that little rather negative than positive: but that with a heavy wheel-load on a flexible rail the creep is decidedly increased by a yielding road-bed.

The author suspects that the amount of creep produced depends on *the violence* of the distortion the rail suffers, rather than its total quantity.

The author then advances a theory of the occurrence of creep in a rail under a rolling load, and finally sums up what is known about creep. Creep, he concludes, is caused primarily by deformations of the rails under the rolling loads, assisted by temperature-changes, which cause fish joints to slip and lessen the resistance. Where track is on a yielding road-bed, creep is intensified, especially under heavy wheel-loads. It is also accentuated by braking, in places where regular stops are made. Creep is greater down-hill than up-hill, but is by no means absent on the latter.

It is usually asserted to be worse in hot weather than in cold. The author thinks it would be more correct to state that the *effects* of creep are more troublesome in hot weather. It, however, comes to much the same thing from the practical permanent-way man's point of view. What probably happens is that the powerful expansion of the rails overcomes the resistance of the fish-plates and allows the creep, which before was kept within bounds by the resistances, to take effect and become troublesome at certain points.

Direction of Creep.—Creep is always with the traffic. On single lines there is normally no trouble with creep. But if there is a great preponderance of traffic in one direction, more or less creep takes place in that direction.

Remedies.—Creep can be resisted more or less completely by putting in enough anchorage or resistance.

The author describes several devices for this purpose, including one of his own design which is in use on the Buenos Aires and Pacific Railway.

Amount of Creep.—It is easy to reduce creep to a small amount by putting in anchors, but it is not easy to suppress it entirely on double lines under modern conditions.

Differential Creep.—In double track the outer rails (the rails near the edge of the ballast) run more than the inner. This differential creep is the most troublesome and expensive of all. In laying double track the author's practice is to set the outer rail back 2 in., and not until it has crept forward "into square" are the rail-anchors applied.

Bad Effects of Creep.—There would be little harm in creep if all the track were "open track," and both rails "ran" equally. Where it compels preventive measures is at connections with other lines, junctions, sidings, crossovers, level crossings with other lines (railway or tramway), swing-bridges, &c. The only practical way to anchor track is over long stretches and through numerous sleepers.

Design of Structures.—Many railway structures are affected by creep, and their design should take it into consideration. This requires special emphasis in the drawing office.

* Abstracts of two papers read before the Institution of Civil Engineers, on Tuesday, January 8, 1918.

II. CREEP OF RAILS.

By HARRY POWELL MILES, M.Inst.C.E.

This paper states that one of the difficulties with which the railway maintenance engineer in this country has to contend is the creeping of rails in a longitudinal direction; and six chief factors in producing the movement are enumerated, only one of which factors tends to move the rails against the direction of the traffic, the other five producing a movement in the opposite direction.

The author then describes briefly the effects which the direction and class of traffic, and the alignment and gradients of the line, have, in producing creep, the effect which the creeping rails have on the constituent parts of the permanent way, and the method of rectifying the positions of the rails after the creep has taken place.

It is observed that it is impossible entirely to eliminate creep, and the most efficient way of reducing it to a minimum is by keeping the road in good order and paying particular attention to having the rails tightly keyed up in the chairs: but, in connection with this, special attention has to be given to the keys and the fishing of the joints during high temperatures, to admit of the rails expanding.

The author then describes investigations of the phenomenon of creeping rails, made by him for a period of five years, on a length of line in this country of which he had charge, consisting of 850 track miles of main and branch lines, over which various kinds of traffic passed.

He takes as a special instance a length of 50 miles of railway where four lines of road run side by side, assigned to different types of traffic, which length of line rises about 330 ft. midway from its commencement, and falls nearly an equal amount to its termination.

Diagrams of this length of line are given, showing:—

1. The gradients and alignment, and the points at which it was necessary to deal with the creeping rails during the five years mentioned.

2. The percentage of rising and falling gradients, and the average annual percentage of the rails pulled back on each of the four lines on these rising and falling gradients.

3. The percentage of lengths of straight and curves on two of the lines, and the average annual percentage of rails pulled back on these straights and curves.

4. The maximum daily temperatures of the four summer months for the five years mentioned, and the total lengths of rails pulled back during each of these years.

The author states what he considers the effect which each of these four cases had on the amount of creep which took place, and in conclusion gives generally the opinions he has formed of the effects which the class of traffic and the gradients and alignment of the line, have in the production of creep.

DRAUGHTSMEN'S ASSOCIATION.—The new general secretary, Mr. Peter Doig, has now entered on the duties of the post, the address of the headquarters office being 140, West George-street, Glasgow.

RESTRICTIONS ON EXPORT FROM U.S.A.—The Ministry of Munitions are drawing the attention of their contractors and agents to the consequences of the system of restrictions on export and priority of orders, which the United States Government is bringing into operation for the purposes of the war. The result of such a system is that private firms desiring to secure export to this country from the United States of munitions, or materials to be used directly or indirectly in the manufacture of munitions, will find it increasingly difficult, if not impossible, to do so except either through, or with the direct assistance of the Ministry of Munitions or other Government Department concerned.

ADMIRALTY APPOINTMENTS.—An important change at the Admiralty has reference to the organisation of the Admiralty Board of Invention and Research, and has the object at once of securing greater concentration of effort in connection with scientific research and experiment and ensuring that the distinguished scientists who are giving their assistance to the Admiralty are more constantly in and amongst the problems upon which they are advising. Mr. Charles H. Merz, M.Inst.C.E., the well-known electrical consulting engineer, who has been associated with the B.I.R. since its inception, has consented to serve as Director of Experiments and Research unpaid at the Admiralty to direct and supervise all the executive arrangements in connection with the organisation of scientific research and experiments. Mr. Merz will also be a member of the Central Committee of the B.I.R., under the presidency of Admiral of the Fleet Lord Fisher. The functions of the Central Committee will, as hitherto, be to initiate, investigate, develop and advise generally upon proposals in respect to the application of science and engineering to naval warfare, but the distinguished scientific experts at present giving their services will in future work much more closely with the Technical Departments of the Admiralty immediately concerned with the production and use of apparatus required for specific purposes. The general arrangements in regard to the organisation of scientific research and experiment will in future come under the direct supervision of the First Lord.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Very little news is ascertainable concerning the Cleveland pig-iron trade. Home sales have been heavy under the very liberal January allocations, and are now practically completed, but there seems little reason to doubt that as in December, owing to difficulty of transit in consequence of scarcity of trucks and shortage of labour many contracts will have to be cancelled at the end of the month on account of non-delivery. Some producers have been compelled to accumulate considerable stocks because they could not get iron away, and this while consumers clamour for delivery. Rather substantial negotiations on foreign account are understood to be proceeding, but scarcity of tonnage has still to be reckoned with in doing business with customers abroad. For home consumption No. 3 Cleveland pig-iron, No. 4 foundry, and No. 4 forge all stand at 95*s.*, and No. 2 is 99*s.* whilst for shipment to France and Italy No. 3 and lower qualities are all quoted 114*s.*, and No. 1 is 119*s.*

Hematite Iron.—Conditions continue stringent in the East Coast hematite branch notwithstanding enlarged output of other steelmaking iron and which has eased the position to a certain extent. Distribution is under the strictest supervision, and whilst this ensures regular supplies to home consumers on a sufficient scale to meet essential needs, the margin available for disposal abroad is very small indeed, and only urgent needs of our allies receive consideration. Nos. 1, 2 and 3 are 122*s.* 6*d.* for home use and 147*s.* 6*d.* for export to France and Italy.

Coke.—The coke market is strong with supplies now none too plentiful. Local needs are heavy. Average blast-furnace quality is 33*s.* at the ovens, and low phosphorus coke 35*s.* 6*d.* at the ovens; whilst foundry is 38*s.* for home use. Foundry description for shipment to neutrals is 45*s.* f.o.b.

Manufactured Iron and Steel.—Producers of manufactured iron and steel are kept very fully engaged endeavouring to cope with the huge Government requirements, and the heavy demands of the shipyards. With these needs absorbing the output ordinary commercial business is practically at a standstill. Among the principal market quotations to home customers are: common iron bars 13*l.* 15*s.*; best bars, 14*l.* 2*s.* 6*d.*; double best bars, 14*l.* 10*s.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 15*s.*; packing iron and steel (parallel), 13*l.* 10*s.*; packing iron and steel (tapered), 15*l.* 15*s.*; steel bars (no test), 15*l.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel joists, 11*l.* 2*s* 6*d.*; and heavy steel rails, 10*l.* 17*s.* 6*d.*

Dorman, Long & Co.—The Lords Commissioners to His Majesty"s Treasury have given their consent to Messrs. Dorman, Long & Co. to issue to their shareholders 240,406 shares as fully paid.

ARMY AND NAVY OFFICERS' PAY.—The War Cabinet have considered the report of the Committee on the pay of Junior Officers, Army and Navy, and have come to the conclusion that, having in view the requirements of the junior officer himself, including upkeep of uniform (the first cost of which is already provided by a grant), his wife, children and other dependent relatives, 10*s.* 6*d.* a day, should be the minimum rate of pay for an army officer of any army as from 1st October last, and for the remainder of the war. The pay of subalterns will be increased accordingly, and certain consequential increases will also be given to captains and majors.

THE LATE PROFESSOR SMOLAN VON SMOLUCHOWSKI.—Professor Smoluchowski, who died at Cracow in September last, was well known also in England because he worked for some time in Glasgow under Lord Kelvin, and was co-author with him and Dr. Beattie of several papers on the changes of conductivity and other effects produced in gases by radiations from uranium and X-ray bulbs and by ultraviolet light. Born near Vienna in 1872, Smoluchowski studied under Stefan and Exner, and was particularly attracted by the thermodynamic researches of Boltzmann, though he never met Boltzmann. Leaving Vienna, he continued his studies at Paris under Lippmann, at Glasgow in 1896–97 (as mentioned), and in Berlin, and became professor in Lemberg, until he was called to Cracow as successor of Witkowski. He was rector of this university, a high honour, when one thinks of his comparatively young age, but a well-deserved honour, considering the breadth and depth of his knowledge. He pointed out that diffusion phenomena formed the macroscopic counterpart of Brownian movements, which he investigated with Einstein, and that it was not necessary to introduce the fictive conception of osmotic pressure in order to account for directed concealed molecular movements; the two conceptions were equivalent, but not identical. As regards thermodynamics he questioned the second law and suggested, that so-called irreversible processes were really reversible. The study of Brownian movements led him to the investigation of colloidal phenomena. He also studied the problems of the atmospheres of the earth and the planets. The opalescence shown by gases near their critical points was explained by him, and he also gave the experimental verification of Lord Rayleigh's explanation of the blue colour of the sky.—We may further mention on this occasion that Professor Ernst Pringsheim, who, years ago, first investigated "black body" radiations, together with O. Lummer, died quite suddenly in Breslau last summer.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

The Industrial Unrest.—The past week has been an eventful one in Sheffield. The promise of the Government to extend the 12½ per cent. under certain conditions to the iron and steel trades, and the appointment of a special Commissioner to consider the adjustment of rates, succeeded to some extent in smoothing the way for a resumption of work. There was still, however, considerable unrest. The Commissioners sat in Sheffield on Tuesday and Wednesday and listened with patience to the grievances of the various unions, and it says much for the finesse and diplomacy of the two Government representatives that at the close of the sittings both employers and employed joined with acclamation in hearty thanks to them for their good offices. Agreements were arrived at which settled most of the outstanding difficulties, though several matters in connection with the lighter trades were left over for consideration at future meetings to be held in London.

Iron and Steel Trades.—After the lengthy stoppage during and following the holidays, operations were generally resumed last week, though most of the week was occupied in again getting plant in order, and actual production was very small. This week all the furnaces are in full blast, and those unions which matter having been satisfied in their demands, there is every prospect of a prolonged period of industrial peace. Government requirements are heavier than ever, and practically every branch of the steel and engineering trades are wholly engaged on work for one or other of the War Departments. The proportion of output which is not directly or indirectly for the manufacture of munitions is infinitesimal. Extreme stringency in supplies of foundry and forge irons continue a feature. The output has been considerably affected by the diversion of many furnaces to the production of basic pig, whilst the advance is a steadily advancing one. Hematites are being allotted to the trade in close rations, and difficulty in obtaining adequate supplies is frequent. Scrap iron is eagerly sought for at top prices. The file trade continues brisk, but makers are unable to compete with the largely increased demand. A business which has during recent months been increasing by leaps and bounds is the manufacture of large circular saws which are used in the breaking up of the timber which is being felled all over the country. A great portion of Sheffield's production goes direct to the Government. Most of the local manufacturers have all their output booked far ahead. Export trade is very limited. A certain amount of steel is going to France, while sickles, saws, and files are in big demand for the South American ports.

South Yorkshire Coal Trade.—The local coal market is stronger than ever, the call for all classes of manufacturing fuel being at a maximum. Best steam coals are practically all taken up by the Government railway and munition works on contract account. Owing to shortage of transport collieries are in many cases refusing to supply except in merchants' own wagons, a condition which has caused some dislocation of business. Works are securing a heavy tonnage of coal and cobbles for current requirements, and during the recent stoppage have been able to accumulate a certain reserve stock. There is little or any, however, on open offer. Current quotations are firm at the maximum. Cobbles, nuts and slacks are readily absorbed on contract account. A good tonnage of gas fuel is going out of hand to inland works. Household sorts are still in good demand. The following are quotations at the pits:—Best branch hand-picked, 23*s.* to 24*s.*; Barnsley best Silkstone, 23*s.* to 23*s.* 6*d.*; Derbyshire best brights, 21*s.* to 22*s.*; Derbyshire house coal, 18*s.* 6*d.* to 19*s.* 6*d.*; best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.*; small nuts, 17*s.* 6*d.* to 18*s.* 6*d.*; Yorkshire hards, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire hards, 17*s.* 9*d.* to 18*s.* 9*d.*; best slacks, 14*s.* to 14*s.* 6*d.*; seconds, 13*s.* to 13*s.* 6*d.*; smalls, 9*s.* to 10*s.*

PERSONAL.—Mr. A. N. Martin, formerly Industrial Agent of the Baltimore and Ohio Railway Company, has resigned. His resignation took effect on the 1st inst., on which date he assumed the position of General Sales Manager of The Fulflo Pump Company, Cincinnati, manufacturers of small centrifugal pumps for machine tools, grinding machines, automobile motors, aeroplane motors, air compressors, &c.—Mr. J. Wilde, Finsbury Pavement House, E.C.2, states that it had been his intention for some time to bring his two sons into the business he established over sixteen years ago. The death of one of his sons and the transfer of the latter's business, to his other son and to himself, has now rendered this arrangement necessary, and his own business of engineer and merchant will be amalgamated with that of his late son under the title of Messrs. John Wilde and Sons, at the above address.—Both the Sheffield Twist Drill and Steel Company, Limited, and Engineering Supplies, Limited, have removed from 28, Victoria-street, S.W.1, to Suffolk House, 5, Laurence Pountney Hill, E.C. 4.—The Government having taken over their offices in Broadway Chambers under the Defence of the Realm Act, Messrs. Ledward and Beckett, Limited, have taken new temporary premises at King's House, King-street, E.C. 2, which is their present address. The same notice applies to Messrs. Bowes, Scott and Western.—Mr. W. J. Sergent, who has for about eighteen years been associated with the Allan Line and Canadian Pacific ocean services, is retiring from active duties as chief superintendent engineer, but continues his connection as an official of the company in a consultative capacity. Mr. Kenneth MacKenzie, M.Eng., who has been his chief assistant, has now been appointed chief superintendent engineer of all the company's fleets, with headquarters in Liverpool.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—Up to the end of last week, and even the beginning of this week, the pits were kept fairly well employed, but advices from the collieries on Wednesday reported a great deal of broken time, and the prospects for the immediate future are by no means promising. The general opinion on the Exchange is that the Coal Controller should now take some definite steps with a view of mitigating the evils which now exist. Efforts are being made to obtain from the Government higher coal prices, and the view is held that those increased prices are bound to be given if production is to continue remunerative; but what is required, chiefly, is a system of regulation which will approximate outputs more closely to the demand. The market is opposed to the suggestion that orders should be allocated, and it is obvious that the authorities will countenance no allocation which will involve the supply of highly volatile coals for the Fleet or for mercantile ship bunkers; but there are those who advocate a general stop-day once a week, while another suggestion is that some of the smaller collieries should be closed down, their owners compensated, and the workmen transferred to other collieries. Recently representations were made that there was a shortage of coke in South Wales, but the position has now materially altered, and local consumers are instructing collieries to reduce their current deliveries by about 50 per cent.

Newport.—There has been a slight improvement in business on the Newport market. This improvement, however, is not very appreciable, and pits are reported idle in both the Eastern and Western Valleys. There is a good demand for coals for inland consumption, but business is on restricted lines and there is no feature of note to report.

Slack Time at Collieries.—The Commission appointed to enquire into slack time working at some of the collieries, particularly in certain areas, has now completed its investigations. Evidence was given by representatives of colliery companies where notices have been, or contemplated to be, given to workmen to terminate contracts owing to lack of work. Based on this evidence the Commission has formulated recommendations, and on Monday last these were forwarded to the Controller of Coal Mines. In the meantime the Executive Council of the South Wales Miners' Federation are suggesting the general adoption of a five-day working week. This suggestion has received considerable criticism. It would, on the face of it, involve a wastage of labour at a time when labour should be utilised to its fullest extent. This intervention on the part of the Executive Council is also resented by some members of the Commission, particularly in view of the fact that the miners were represented on the Commission by their general secretary (the Right Hon. T. Richards, M.P.).

The Supply of Pitwood.—The supply of pitwood is scarce, and although the few consignments arriving are being delivered to the collieries at the new maximum price of 65*s.*, local importers have not been informed of any arrangement for the regulation of f.o.b. prices in the Bay, and are fearing a further diminution of supplies. The compulsory obligation on the part of shipowners to load pitwood home is said to be used by merchants at the moment as a lever for cutting rates. Bordeaux has been done the last few days at 17*s.*, if not at a lower rate, as compared with 22*s.* a few weeks ago, and an intention is avowed of driving them down to 14*s.* Owners are resenting this pressure, and are taking counteracting measures.

ROYAL METEOROLOGICAL SOCIETY.

THE annual general meeting of this society was held on Wednesday, 16th inst., at Caxton Hall, Westminster, Major H. G. Lyons, F.R.S., President, in the chair. The report of the council for 1917 was read, and the Symons Memorial medal, which is awarded biennially for distinguished work in connection with meteorological science, was presented to Dr. Hugh Robert Mill, F.R.S.E., director, British Rainfall Organisation. The council for 1918 were duly elected, the president being Sir Napier Shaw, F.R.S. Major H. G. Lyons, F.R.S., delivered an address on "*The Meteorological Resources of the Empire*," of which the following is an abstract:—

In many directions steps are being taken to take stock of the resources of the Empire, and to plan how these may best be utilised in the general reconstruction which must undoubtedly be taken in hand on the cessation of hostilities. In Meteorology the same should be done, for within the Empire we may meet every type of climate. The great oversea Dominions, India, the colonies, and especially the oceanic islands, not only afford the means for extending our knowledge of the direction and velocity of the currents of the upper air, to meet the demands of aviation, which will become greater in the near future, but with a very moderate increase in the resources of their existing institutions, and more active co-operation, they may powerfully aid in the solution of many meteorological problems of theoretical and practical importance.

But the organisation of the Empire's meteorology at the present time is very far from being adequate, for the provision of stations has grown out of local needs or individual initiative, not from a considered plan. When we examine the meteorological organisations of the Empire we may well be astonished at their extent and their development, but as we look farther into the matter we shall see that we are still far from utilising them to the best advantage, for reasons which will appear.

In all countries where there is a meteorological service the network of climatological stations is controlled by one or more first order stations or meteorological observatories at which continuous records or hourly readings of pressure temperature, wind, sunshine and rain, &c., are taken, but none as yet exist in the great colonial regions of East Africa, West Africa, or in the West Indian Islands, though there are 18 institutions of this class in other parts of the Empire.

The work of the meteorologist does not end with recording the pressure or the temperature or the monthly amount of the rainfall, but meteorological observations, after being taken, must be worked up into the various forms in which they will be most useful for shipping, agriculture, water supply, engineering, sanitation and health, and now, also, aerial transport. The same form will not suffice for all, and meteorology itself has its own especial needs, but the important thing is that this information, however accurate and detailed it may be, will not be available in exactly the forms that answer to different requirements, unless there is a sufficient staff of trained meteorologists to handle it and to supervise its preparation.

Nor is the study of a single region sufficient in itself. India, in preparing the monsoon forecast, draws upon data from Egypt, St. Helena, Brazil, &c.; Egypt, in forming each year an estimate of the coming Nile flood, utilises information from India, Uganda, the South Atlantic and so on. The East India Islands need warnings of their hurricanes from the more eastward islands of their archipelago, and must utilise all that Asia and Africa can tell them about the development and movement of tropical storms before their precautions can be considered to have exhausted all the means available. All lands which lie near the subtropical zones of scanty rainfall are vitally interested in the problems of forecasting the probable sufficiency or failure of their rainy season. The droughts of the pastoral regions of Australia and South Africa are well known, and the same occur in the Sudan, though from its retarded development less has been heard of them up to the present time, but in the future as the population increases and becomes more settled the same considerations will demand attention. Similarly, the countries in temperate zones find some of their most urgent problems in the adequacy or inadequacy of the summer heat for the ripening of cereal crops.

We are far from having solved these problems, but we know enough to say definitely that they cannot be solved from the study of a single region; that they are world-problems in which the meteorological conditions of the whole world must be considered; and for studies of such vast importance the British Empire offers unequalled opportunities, which must be seized, and fully utilised. It is in the development of our science within the Empire that there are opportunities by which we have hitherto profited inadequately.

In East and West Africa we have two large groups of colonial possessions having closely related climates and being already in possession of a number of meteorological stations with records extending over a considerable number of years. It should not be beyond the wit of man to devise a workable system of co-operation for these stations so as to form for each a service which should have a meteorological observatory as its technical centre, with one or more trained meteorologists to direct its energies and to utilise the collected information for the use of the colonies themselves and of the Empire as a whole.

Already a secular decrease in the annual rainfall of Nigeria has been not merely suggested as being indicated, but announced as a fact, so that the confirmation or confutation of this contention is a matter of very urgent importance to the colony. Such questions as these are best investigated on the spot by a trained meteorologist in the first instance, even though the final stages in the inquiry may require reference to the meteorological authorities of other regions for the results of their investigation into similar or related questions.

We see, therefore, that within the Empire there are already upwards of 1,000 climatological stations distributed all over the world, from latitude 60 deg. N. to latitude 54 deg. S., near the equator, within the tropics, and in the temperate zone. They are on coast lines, in the heart of continents, on oceanic islands. Some few, especially in India, are at high altitudes above sea-level. They therefore furnish us with opportunities for investigating almost any problem that may arise in meteorology if competent meteorologists make full and proper use of them.

We come, then, to the conclusion that, in order to provide reliable and adequate information regarding the climate of the Empire, and the meteorological phenomena which play so important a part in the lives of all the inhabitants of the earth, a more efficient organisation of our meteorological resources is necessary.

In the first place men will be required who have received a good training in modern meteorology, and have such a knowledge of physics and mathematics as will enable them to deal with the problems which they may meet.

Hitherto there have been very few of these men in this country, but the present needs have brought a number into direct contact with the subject, and if the meteorological services of the Empire are going to offer a career to an able meteorologist, some of them may elect to adopt it.

Co-operation and intercommunication will be all the more essential and valuable when the meteorological work is entrusted to specially-trained men who have seriously studied the subject, and this society should be able by means of its meetings and especially by its Journal to aid powerfully in the attainment of this desirable object.

THE MICROSTRUCTURE OF WROUGHT IRON.

(*For Description, see Page* 77.)

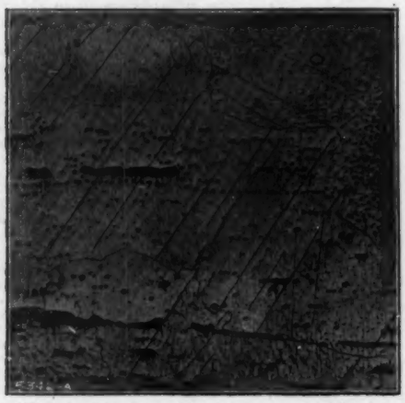


FIG. 1. UNUSUAL FEATURES IN THE MICROSTRUCTURE OF WROUGHT IRON.

The dark lines, parallel within any single grain, are the Neumann lines. The mottled appearance of the corner grains indicates the nonhomogeneity of the ferrite due to the unequal distribution of the phosphorus. Specimen: W 1, longitudinal section. Magnification, 66; etching, 10 per cent. alcoholic nitric acid.

FIG. 4. UNUSUAL MICROSTRUCTURAL FEATURES OF WROUGHT IRON.

(*a*) Specimen W 1, longitudinal section. The streaks exhibiting the unusual etch-pattern are very often composed of grains which are much larger than the average for the piece. Magnification, 66; etching, 10 per cent. nitric acid.

(*b*) Specimen W 22, longitudinal section. Low-carbon steel sometimes exhibits a structure similar to the unusual features in wrought iron. Magnification, 333; etching, Stead's reagent.

FIG. 6.

(*a*) Alloy containing 0.37 per cent. phosphorus, in cast condition. Magnification, 16; etching, alcoholic copper chloride acidulated with hydrochloric acid.

(*b*) Same material as *a*. Magnification, 66; same etching.

The dark areas are portions of the ferrite high in phosphorus; *b* shows some of the eutectic as islands in the midst of the dark areas.

FIG. 7.

(*a*) Eutectic consisting of iron phosphide and the saturated solid solution of phosphorus in ferrite, from a cast alloy containing 0.37 per cent. phosphorus. Magnification, 333.

(*b*) Iron-phosphorus alloy, 0.48 per cent. phosphorus after heating 24 hours at 790 deg. C. The eutectic has disappeared by dissolving in the ferrite, although the diffusion of the phosphorus throughout the ferrite is still incomplete. Magnification, 66.

In both cases the ferrite high in phosphorus has been darkened by etching with copper chloride acidulated with hydrochloric acid.

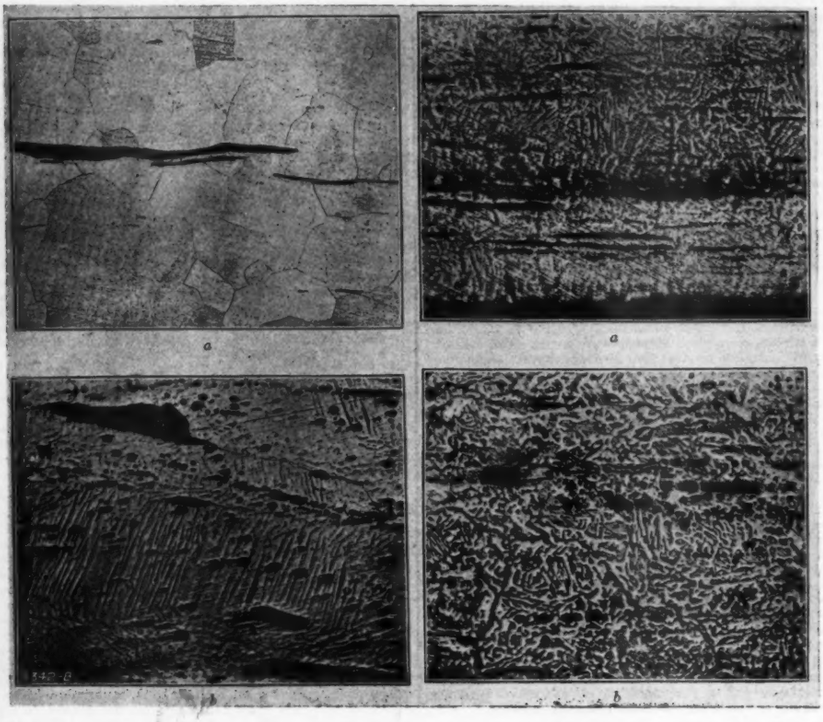


FIG. 2. USUAL AND UNUSUAL MICROSTRUCTURE OF WROUGHT IRON.

(*a*) Microstructure of a longitudinal section of Swedish iron. Magnification, 66; etching, 2 per cent. nitric acid.

(*b*) Longitudinal section of specimen W 1, showing the mottled etch pattern occurring as parallel transverse bands within the grains. Magnification, 66; etching, 10 per cent. nitric acid.

FIG. 3. UNUSUAL MICROSTRUCTURAL FEATURES OF WROUGHT IRON.

(*a*) Specimen W 5, wrought-iron pipe, longitudinal section.

(*b*) Specimen W 4, wrought-iron pipe, longitudinal section.

Etching, alcoholic copper chloride acidulated with hydrochloric acid (Stead's reagent). Magnification 66. The portions shown are from the streaks upon which copper did not deposit.

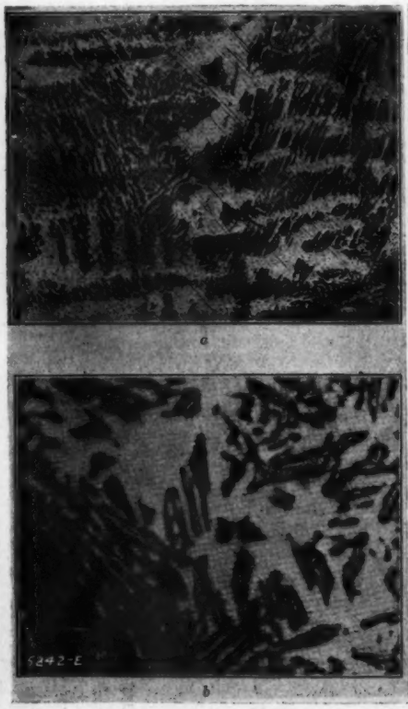


FIG. 6. MICROSTRUCTURE OF IRON-PHOSPHORUS ALLOY.

FIG. 7. MICROSTRUCTURE OF IRON-PHOSPHORUS ALLOY.

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The charge for advertisements is three shillings for the first four lines or under, and eightpence for each additional line. The line averages seven words. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
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NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, January 18, at 6 p.m., at the Institution of Civil Engineers, Great George Street, Westminster. Papers to be presented:—"Traction on Bad Roads or Land," by Mr. L. A. Legros, Member, of London, and "Utility of Motor Tractors for Tillage Purposes," by Mr. Arthur Amos, of Cambridge.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, January 18, at 8 p.m., at 39, Victoria Street, Westminster. "Power Plant, Maintenance and Advantages of Steady Running" (illustrated by lantern slides), by Mr. R. Rankin, M.I.E.E., Chairman of the Institution. Saturday, January 19, at 7.45 p.m., at the Dartford Technical Institute. Mr. F. W. Lanchester, M.Inst.C.E., will preside at an inaugural meeting of a new local section of the Junior Institution of Engineers for members in Gravesend Dartford district. Tuesday, January 22, at 8 p.m., in the Lecture Hall of the Royal Society of Arts, John Street, Adelphi, London, W.C. The President of the Institution, Mr. F. W. Lanchester, M.Inst.C.E., will deliver a Presidential Address. The title of the address will be:—"Industrial Economics During and After the War."

THE ROYAL SOCIETY OF ARTS.—Monday, January 21, at 4.30 p.m. Cantor Lecture.—"High-Temperature Processes and Products," by Mr. Charles B. Darling, A.R.C.Sc.I., F.I.C., Lecturer in Physics, City and Guilds Technical College, Finsbury. Lecture I: "Methods of Producing High Temperatures."—Special Fuel Furnaces—Oxy-Hydrogen Flame—Oxy-Acetylene—Thermit—Electric Furnaces. Wednesday, January 23, at 4.30 p.m. Ordinary meeting.—"Water Power in Great Britain (with special reference to Scotland): its Amount and Economic Value," by Mr. Alexander Newlands, M.Inst.C.E., Chief Engineer, Highland Railway. Sir Dugald Clerk, K.B.E., D.Sc., F.R.S., Member of the Council of the Society, will preside.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS (LONDON CENTRE).—Tuesday, January 22, at 4 p.m., at the Royal Society of Arts. A paper will be read, on "The Metric System for the British Empire," by Mr. A. J. Stubbs, M.Inst.C.E.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, January 22, at 5.30 p.m. Papers to be submitted for discussion:—"Rail Creep," by Mr. Frank Reeves, M.Inst.C.E., and "Creep of Rails," by Mr. Harry Powell Miles, M.Inst.C.E.

THE LIVERPOOL ENGINEERING SOCIETY.—Wednesday, January 23, at 8 p.m., at the Royal Institution, Colquitt Street, when a paper will be read by Mr. Harold Walker, entitled "Steam Boilers—their Design and Construction."

THE CONCRETE INSTITUTE.—Thursday, January 24, at 5.30 p.m., at Denison House (close to Victoria Station), when a paper will be read, on "British Trade and the Metric System," being the proof of the existence of a tripod or triple scale in British weights and measures and of the subordination to the tripod theory of the metric theory, by Mr. E. A. W. Phillips, M.Inst.C.E.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, January 24, at 6 p.m., at the Institution of Civil Engineers, Great George Street, Westminster, S.W. "Telephone Exchange Transfers and their Organisation," by Mr. F. G. C. Baldwin, Associate Member.

THE ROYAL INSTITUTION OF GREAT BRITAIN. — Friday, January 25, at 5.30 p.m. A discourse will be delivered by Professor John S. Townsend, F.R.S. The subject is "The Motion of Electrons in Gases." Afternoon lectures next week at 3 p.m. Tuesday, January 22. Professor W. M. Flinders Petrie, D.C.L., Litt.D., F.R.S., on "Palestine and Mesopotamia; Discovery, Past and Future" (Lecture II). Thursday, January 24. Professor Spenser Wilkinson, on "Generalship—a Campaign of Napoleon's (1806)" (Lecture II). Saturday, January 26. Professor William J. Pope, LL.D., D.Sc., F.R.S., on "The Chemical Action of Light" (Lecture II).

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal from 6d. to 8d. per copy. This increase dated from and included the issue of Friday, March 16. The change will not apply to unexpired subscriptions.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, JANUARY 18, 1918.

LUBRICATION.

WE believe it was Disraeli who suggested that a country's consumption of sulphuric acid constituted a fair criterion of its industrial status. But few trades, however, make direct use of sulphuric acid, whilst all without exception find a need for lubricants. If it be permissible to use any one commodity as a standard for comparing the manufacturing activities of a people, the consumption per head of lubricating oil would undoubtedly form a better criterion than sulphuric acid. Tens of thousands of tons of lubricating oil are consumed annually in this country, and it would probably be no exaggeration to say that it is mostly wasted. It is only of recent years that much attention has been directed to the importance of economising oil. So long as supplies are plentiful and cheap it is only the large user who considers the possible saving of oil as outweighing the prime cost of improved fittings, or that of the skilled supervision which is essential for the best results. The small user may prefer, for example, to adopt a solid lubricant for his shafting, and considers the additional expenditure of power as compared with what would be required with oil lubrication as fully offset by the simplicity and reliability of the system. The recent rise in the cost of coal, which is, we fear, certain to remain high for years to come, would itself act as a strong incentive to a closer study of the lubrication problem, and, as matters stand, a still more powerful motive is provided by the phenomenal rise in the price of the usual lubricants. This, it is to be hoped, will prove but a passing phase, although the growing demand for liquid fuels has reduced the supply otherwise available for lubrication, and will probably prevent prices falling to quite the old level. The smaller the demand for lubricants can be made, the lower will be the price at which they can be obtained, so that economy in their use will be doubly blest.

The experience of railway companies in this respect has been highly instructive. The advantages of an expert study of the question was perhaps first realised in America, when the Galena Oil Company contracted to lubricate the whole of the rolling-stock on certain railroads at fixed charges which showed a very substantial saving on the then current practice of the roads. This contract nevertheless proved highly profitable. Lubrication specialists, with full powers to experiment and authority to see that their advice was followed, soon reduced the oil consumption to an astonishing degree. Similar success has followed their introduction on our own railways, where, however the work has been undertaken by officials responsible to the company and not to an outside contractor. The railways had of course the advantage that their scale of operations made it possible to employ really competent men for the task. Our principal railways, for example, consume each some 3,000 tons of oil yearly, and the total for the whole of the lines in the kingdom cannot fall far short of 60,000 tons per annum. In *ante* war days this oil averaged about 8*l.* a ton, but present prices are at three times as much. Other oil consumers who, working on a smaller scale, are less able to secure competent advice and supervision, must suffer from this rise much more seriously than the railway companies do.

The principal task before us at the present time is to improve the lubrication of slow-speed machinery. The problem so far as high-speed machinery is concerned is now well understood, both from the theoretical and practical standpoints. According to the theory the oil forms a continuous film between the brass and the journal, which are nowhere in contact under normal running conditions. This conclusion is often disputed by millwrights accustomed to ordinary line shaft bearings, but it is supported by certain very cogent facts. Turbine bearings carrying several tons at speeds of 1,000 r.p.m. or more, when examined after years of service show on the brasses the original scraper marks. A very striking experiment confirming this view was described by Professor A. Kingsbury in a paper published by the American Society of Naval Architects in 1897. A short shaft, 6 in. in diameter and 6¼ in. long, was run in a C. I. bush of $\frac{1}{1000}$ in. greater diameter, with air as the sole lubricant. Both surfaces were quite dry, and at starting there was a grating noise. As the speed rose, however, this disappeared and the torque required diminished, until finally the shaft floated on the film of air. That there was then no contact between the journal and the bush was proved by coupling up an electric bell in series with the bush and journal. At slow speeds the bell rang continuously, but when a certain limit was exceeded it became and remained silent, thus showing that the shaft and bush were completely separated by the non-conducting air film.

An attempt was indeed made some years ago to apply air lubrication to cotton spindles. Unfortunately the attempt was unsuccessful, and the millions of spindles at work in Lancashire have still to be lubricated with oil and under conditions which make economy of lubricant almost impracticable. With forced lubrication or some equivalent

method of supplying a continuous stream of oil slow-speed bearings show the same absence of wear as high-speed bearings. In all these cases a good agreement is found between Reynolds' theoretical conclusions and actual experiment and experience. The governing factor is the viscosity of the lubricant, no other quality except that of chemical stability being of much importance. Some oils, of course, otherwise satisfactory are liable to "sludge" when used in the crank cases of high-speed engines, but in all other respects the quality of the lubricant is substantially fixed by its viscosity under the actual conditions of use.

With such methods of imperfect lubrication as are almost unavoidably adopted for millions of bearings, matters are by no means so simple. Of two different lubricants having the same viscosity as tested in the viscosimeter one may prove satisfactory and the other very much of a failure. It has accordingly become the practice to speak of the oiliness of a lubricant as something to be distinguished from its viscosity, though no very clear definition of what physical qualities are thus represented has yet been forthcoming. The term simply seems to imply that the lubricant can be satisfactorily used in cases where the supply is intermittent.

It seems probable, nevertheless, that this quality still corresponds in the main to the viscosity of the oil at the actual point or points of lubrication, which may be quite different from its value as determined in a viscosity meter in the usual way. Reynolds indeed showed that the slipperiness of ice was simply due to efficient lubrication. Ice is no smoother than glass, but at normal temperatures it readily liquifies under the pressure of the skate, congealing again as the skater passes on. The film of liquid thus formed under the skate is a perfect lubricant which cannot be squeezed out, since further pressure will produce a fresh supply. At very low temperatures ice is stated to lose this property and be no more slippery than so much glass. In cases of imperfect lubrication the load is presumably concentrated on a number of isolated spots, at which the pressure will be correspondingly high. It has, indeed, been shown that an oil film can support extraordinarily high pressures. Thus, in some experiments made in America with thrust blocks of the Michell type it was found that an oil film would carry without failure a pressure of five tons per square inch, the rubbing speed being some 50 ft. a second. This pressure, it should be added, is an average value, the maximum being necessarily materially more. In fact no limit can yet be fixed as to the pressure which an oil film can sustain without losing its continuity. As long as the film is continuous the opposing surfaces cannot come into contact and lubrication will be satisfactory.

According to Reynolds' theory the carrying power of a film varies inversely as the square of its thickness, and if a bearing is imperfectly lubricated it seems likely that most of the load may be borne by isolated spots standing above the general level of the brass. There is evidence that the viscosity of a liquid increases considerably when subjected to very high pressures, and this may be a factor in fixing the value of a lubricant for use in unfavourable conditions. Another factor involved is that if the pressure be concentrated as suggested, the local temperature of the oil may be considerably above the average temperature of the brass. That two lubricants have the same viscosity at atmospheric pressure and at the average brass temperature is of course no adequate evidence that the equality persists at much higher temperatures and pressures. A high local temperature may perhaps suffice to determine chemical changes in one of two oils, whilst the other, having greater stability, might remain unaffected. Moreover, if as suggested, the load on an imperfectly lubricated bearing tends to be concentrated at certain spots, a lubricant of high compressibility would tend to distribute the load over a greater area, giving a correspondingly greater thickness of the effective film. It is, we think, along these lines that an explanation of the anomalies in the behaviour of lubricants when supplied intermittently is to be sought, though differences in the surface tension may also have a bearing on the problem. The successful lubrication of the pallets of a clock escapement is commonly attributed to this factor. The actual lubrication is no doubt due to the viscosity of the film between the pallet and the escape wheel tooth, but it is the surface tension which ensures that this film shall be restored to its original thickness when the tooth lifts, and then be ready to perform its duty at the next contact. Similarly the surface tension of a lubricant may well play an essential part in ensuring the maintenance of the film under the high spots of an imperfectly lubricated bearing. As the film is dragged out from under the bearing point by the journal surface, it must be restored to its original thickness before the revolution is completed and it is again called upon to take the pressure.

The American experiment, already referred to, also seems to throw some light upon the reason why white metals prove so satisfactory as a lining for brasses. In that experiment, as already stated, the pressure rose to an average of five tons per square inch. This the oil film carried without failure, but the bearing metal began to flow, thus bringing the experiment to an end. If the view above put forward be sound and the pressure on imperfectly lubricated brasses is concentrated on isolated spots, this property the white metal possesses of flowing under heavy local pressures should be highly advantageous, as it would tend to increase the area of contact. This in its turn would give a thicker film, less friction, and a lessened danger of the temperature becoming dangerously high at the bearing points.

The peculiar lubricating properties of graphite are perhaps due, at least in part, to a similar reduction of the irregularities of the opposing surfaces. The adherence of graphite to most surfaces exceeds its tenacity, at least so long as the graphite is of not more than average purity. It is in virtue of this property that the lead pencil leaves its mark on paper. If the graphite adheres to the opposing surfaces of a journal the depressions will tend to be levelled up, with the result that the load will be less liable to be concentrated on isolated points.

THE PETROLEUM INDUSTRY OF RUMANIA.

WHEN the Institution of Petroleum Technologists met last Tuesday, it was to listen to a paper, not on petroleum prospects in this country or some portion of the Empire, a question lately discussed, but to a communication on an actual petroleum industry, in Rumania, a land which, though not in the very front rank of the petroleum-producing countries, such as North America and Russia, certainly belongs to the most important oil countries and owes a good deal of its modern development to this natural resource. The author of the paper on "The Petroleum Industry of Rumania," Captain T. S. Masterson, D.S.O., was also able to give some information on engineering features, though, owing to reasons which do not at present require elaboration, his communication was less detailed and comprehensive than he had intended it to be. Captain Masterson has been working in the Rumanian oil fields for many years.

The Rumanian oil fields are in the tertiary rocks skirting the foothills of the Carpathians to the south, and also the east of Transsylvania, in Wallachia and also Moldavia, roughly north of Bukarest. The oil fields, Captain Masterson stated, were among the most healthy of the world, being situated at altitudes ranging from 500 ft. to 2,000 ft. above sea level. The climate of the country was rather severe, the winter temperature being often below 0 deg. F., the summer above 100 deg. F. in the shade; but the oil fields themselves enjoyed a more temperate climate, owing to their sheltered position. Five lines linked the Rumanian railway systems with Austria Hungary, two lines with Russia, one line with Bulgaria. With the exceptions of Campina and Baicoi all the fields were miles away from the railways and accessible only by inferior roads, sticky with clay, whilst the main roads were well metalled and well kept. The peculiar Rumanian land-tenure laws made the question of mining rights difficult and intricate. The subsoil was, so far as oil was concerned, the undisputed property of the surface-owner. Up to 1864 the land had practically belonged to the monasteries and landed proprietors (boyars); in 1564 the Government seized the monastic estates, freed the peasants, formerly serfs, and granted them 3,000,000 hectares in small holdings not exceeding 6 hectares (15 acres). Sons and daughters shared equally in the inheritance, however, and most plots were not larger now than 1 acre; many in fact did not exceed ¼ acre. The bulk of the actual petroleum concessions were on peasant land or mosneni (elders') land. In both these cases the legal titles were mostly very doubful, and the concessionaire found himself involved in expensive and interminable lawsuits. The law of consolidation, of 1904, had improved matters, but there remained great difficulties, increased by fraud and blackmail, and even a consolidation might not be a guarantee of security of tenure; the position was not quite satisfactory in 1916.

Reviewing the geology of the oil district Capt. Masterson stated that the actual finds had not always fulfilled the predictions of the experts, and that it was unknown whether the gravel terraces of the plains adjacent to the hills concealed further oil treasures. In the early days the oil had been mined by means of hand dug shafts, which in the Bustenari district gave the impression of a human beehive. Holes, 3 ft. or 3½ ft. in diameter or square, were made in the ground and lined with twigs of trees like wicker work or with 2-in. oak or beech timber; some of these holes extended to a depth of 900 ft. The digger, the putzar, who worked in the bottom of the hole, was tied by a hemp line to the gin on top and was supplied with fresh air through primitive bellows and 8-in. pipes; he wore leather skins and a tin hat and sent up buckets full of the sand or rock. As there was always a danger of suddenly striking an oil source, a ⅝-in. sounding rod was driven 10 ft. or 12 ft. below the level at which the digger worked; if oil at once issued forth, the digger mostly had time to escape. Frequently, unfortunately, the man was buried in oil and oil sand and remained buried for months, before the oil level could be reduced and the hole be cleared. As much as 20 tons of oil had been raised per day in this primitive manner from depths of 500 ft. Only a few of these hand-wells were still in existence in 1916. With the influx of foreign capital since 1898 the industry had rapidly developed, as the following statistics prove. The total production of Rumanian oil had in 1904, 1907, 1910, 1913, 1915 amounted to tons: 500, 561; 1,127, 297; 1,352,407; 1,885,225; 1,673,145. In 1915 the chief fields had yielded: Campina, 120,657; Bustenari (four groups of wells), 285,000; Baicoi, 178,000; Moreni, 741,165 tons. In that same year the whole industry comprised about 2,100 borings, of which 48 per cent. were more or less productive, 18 per cent. were drilling and repairing, and 34 per cent. held in suspense or abandoned.

The first drillings, since 1884, on the old Pennsylvania system, had technically failed, because the borings became too small in diameter or got out of plumb, or were not pushed deep enough, and because the beds would not stand up in the drilling unless the casing followed closely. The next system tried, the Canadian, "made good," although progress had been very slow at first, when the under-reamer had constantly had to be used; quicker progress was later made with eccentric bits; the persistence of the system down to 1916 was partly due also to the accumulation of Canadian boring material and tools. After 1898 various water-flush percussion systems (Vogt, Treschl, Travzl, Mahrenholz) were adopted, chiefly by contract drillers; local prejudices, and at first also the companies, did not favour these systems, until certain companies, such as the Astra Romana and the Steaua Romana, purchased their own plant; the "Alliance" rig of the latter company, in particular, was a notable success. In 1904 the Standard Oil Company reintroduced the Pennsylvania system with American drillers and a large consignment of plant, of a heavier type than that used before. Again, the casing, including the heavier type of "drive pipe," would not drive through gravel and sands, especially not at depths exceeding 1,000 ft.; with the aid of calf-wheels and under-reaming the system became a success in

three years, however, at expenses which would have broken ordinary companies, but not before adapting the system to the insertion of casing *paripassu* with the advance of drilling.

The water-flush percussion system had been labouring under the same difficulties in the early days when clear water was used for flushing, and casing had to follow the drill as with the dry systems. When first tried in 1904 or 1905 the rotary system had not answered, either because the plant was light or not suitable for the particular conditions. The re-introduction of the rotary in 1912 had again not been successful, largely for reasons of administrative nature; but the rotary proved a success in the following year on suitable rock, and Captain Masterson expected its wide use in the future. In the loose, sandy marls between Gura Ocnitei and Tzintea it had been a great success; there the use of thick mud flush had made it possible to drill 1,600 ft. of uncased hole, and at Bana Moreni wells had been drilled to 2,400 ft., at an average progress of 65 ft. per day, including the time needed for the setting of two strings of casing and the exclusion of water in the upper sands. That record compared very favourably with the achievement of the percussion-flush system, and daily drilling records of 250 ft. and 300 ft. of 12-in. hole had been frequent. In the sandy, small-gravel beds of Tuicani the rotary had also shown its advantage over the percussion systems, but not in beds of gravel and large boulders, in the conglomerates of Baicoi, and in the sandstones of Chiciura and Gropi, where the 24 hours' progress often did not exceed 14 in. This low efficiency was partly ascribed to the inferior steel available for the bits, which turned blunt after 10 minutes and began to wear; in gritty rock the bits had to be pulled out and exchanged at close intervals. The Sharp and Hughes bits had not sufficiently been tested, suitable sizes not being available. In drilling big holes through hard sandstone, ledges might be left on the rock; they had to be removed by reaming for the insertion of the casing, which took as long as the original drilling; guides above the bit did not always exclude this trouble and were dangerous tools in the holes.

The combination-rig of the rotary and the ordinary percussion systems was not satisfactory where hard shells were met with; the advantage was then lost that no casing was needed because, in the absence of thick mud-flush, casing had to be inserted before the mud in the hole was thinned for cable and solid-rod drilling. To overcome this difficulty, Captain Masterson had himself added a bull wheel to the rotary derrick and a crank to the lengthened drilling shaft with the object of using hollow flush poles for spudding through the hard shells. The derrick was not overburdened then, casing could be dispensed with, and no time was lost by changing from one system to the other. One charge brought against the rotary might also be made against other systems when used with insufficient care: that the speed of advance and the heavy weight of the flush-mud allowed oil sands to be drilled through and "mudded-off" without being observed. Captain Masterson's own observations convinced him that, with vigilance, no oil-sand need pass unobserved, even where there was no big gas pressure, and inquiries as to the results, obtained with rotary bores elsewhere in Rumania, supported that view. There was one more point in favour of the rotary. On account of the mudding-up of the walls, it facilitated the shutting-off of water, particularly when the hydrostatic pressure was not great; that advantage was lost where the annular space behind the casing had to be washed for the purpose of using cement. Summing up this section of his paper, Captain Masterson said that no one system could generally be recommended, as each system had its advantages and disadvantages. In already exploited fields, a proper choice of system could generally be made; in unexplored fields, the percussion system seemed to be advisable, as the operator would be unacquainted with the characteristics of the rocks to be drilled. Captain Masterson showed some photographs, illustrating the primivity of the hand-dug wells and their working—which, the President of the Institution, Mr. Charles Greenway, remarked, strongly resembled the methods and devices that had been used in Burmah from ages immemorial—and illustrating the oil-fields of Campina and Bustenari, with their derricks crowded together as much as small town houses, and the immense clouds of black smoke hanging over the work of destruction in November, 1916. There were no diagrams of the machinery, and no further explanations of the most interesting engineering features.*

Passing to the questions of labour, supplies and refinery, Captain Masterson stated that the labourers and drillers had been, in turns, Americans, Poles from Galicia, and, finally, Rumanians; the Rumanian peasant, who was superseding the American driller, was intelligent and conscientious, but was slow to grasp mechanism, as was natural in an agricultural country. As regards supply of materials, timber came from the Carpathians, the cement was made locally, but all metals and textiles were imported. Germany supplied the entire requirements of casing, tank plates, electric plant and refinery commodities, as well as most of the pumping and workshop plant and their raw materials; England's share in these supplies was altogether insignificant. The 61 refineries of Rumania could treat a total of four and a half million tons of crude oil per annum, whilst the maximum annual production of 1913 had only come up to 1.9 million tons. The eleven largest refineries, as Ploesti, Campina, Tergoviste, Baicoi, Buzen, and Plopeni, dealt with 85 per cent. of the output. The total capacity of the iron tanks was 1,450,000 tons. Many pipe lines, from 2 in. to 6 in. diameter, and up to 45 km. in length, brought the crude oil to the refineries and loading stations; the total pipe length was 1,300 km. To this had to be added the State lines leading from the field-centres across the Danube at Cernavoda to the port of Constantza on the Black Sea; that line was not completed when the war broke out. For internal distribution and conveying the exports to the sea and the Danubian ports, 4,200 tank-wagons had been used.

Concluding, Captain Masterson said that Rumania entered the war in August, 1916, In November the Rumanian Government, in the interest of the Entente cause wisely agreed to destroy its oil industry, and to deprive the enemy, as far as was possible, of the advantages which her prospering oil industry might afford. Huge stores of oil were destroyed, the tankage was blown up, and the wells and refineries were subjected to the maximum amount of damage and destruction which the short time available permitted. "It was the author's painful duty to be amongst the last to see the flames consuming an industry, the building up of which he had witnessed almost from its inception." On re-occupation of the territory Rumania would be faced with one of two problems; (1) Either the industry would be more completely destroyed than it was when left in December, 1916, or (2) it would be found with such improvements as might have been effected under German occupation. It had been stated in Rumania that the Allied Governments had promised to compensate Rumania for the damage done.

The question, whether or not exports of oil are at present taking place from Rumania, about which contradictory reports have appeared in the Press, was not touched upon. But Captain Masterson's last remark—the paper was in type—had induced Sir W. Watson Rutherford to point out in a letter that the compensation was due, not to the Government of Rumania, but to the private owners. This letter, which was read by the honorary secretary, Mr. A. W. Eastlake, tended to divert the discussion from technical features almost into political questions. Some further information about local geological and other features was elicited and given by the speakers, Messrs. Guttentag, L. Hamilton, Mollwo Perkin, L. Gaster and D. A. Sutherland,—little of interest to the engineer, however. The chairman inquired whether, with only half the wells actually producing in 1915, the average cost of production was not high, and Captain Masterson gave some figures. In agreement with several speakers he also said that oil of any quality was being obtained in Rumania; his analytical notes showed percentages of benzine up to 50 per cent. and more. One peculiarity of the Rumanian fields mentioned was that the oil coming from the one side of an anticline may contain solid paraffins which is absent in the oil from the other side. The great variety of the oils and the possibility of getting good lubricants from it, had already been shown in the excellent book on Rumanian petroleum by Edeleanu, which Mr. L. Gaster translated. Mr. Guttentag regretted that, apart from the translation of this book, which was ten years old, and from Captain Masterson's paper, there was practically no English literature on the subject. He also directed attention to the educational value of the Rumanian oil fields for post-graduate study; the Institution of Petroleum Technologists might send out students to suitable centres, as the institution of Mining and Metallurgy did. Several speakers, we should not omit to add, expressed a liking for the Canadian system, and Mr. Sutherland said that Rumanian oilfields had hardly been scratched.

* Information concerning the mud-flush working in particular will be found in our article on "the Waste and Control of Natural Gas," ENGINEERING, August 10, 1917, page 153.

THE SETTING OF CEMENT AND PLASTERS.

IN opening the general discussion on "*The Setting of Cements and Plasters*," by the Faraday Society last Monday, January 14, Mr. James Swinburne, F.R.S., a Past-President of the Society, remarked that the Society had hoped to institute a new research of the problems. Though that hope has not yet been realised, the discussion, by broadening the scope of the questions at issue, proved quite as instructive to the scientists, architects and engineers attending the meeting as the previous discussions of the Society have been. A good deal has been done during quite recent years towards the elucidation of the problems of the setting of cements which are as old as civilisation. The meeting, held at the Royal Society of Arts, was opened at 5.30 p.m. and continued after a dinner interval till 10.20 p.m. The reading of eight of the nine papers on the list was taken in the afternoon, leaving the evening practically free for the general discussion.

The discussion was introduced by Dr. Cecil H. Desch in a most able review of "*The Mechanism of the Setting Process in Plaster and Cement.*" Distinguishing between plasters (comprising simple chemical cements such as magnesia cement) and mortars and cements proper, Dr. Desch stated that the setting of plaster was essentially a recombination with water of the gypsum,* which had been deprived of its water of crystallisation by the burning process, to a mass of interlaced crystals. The mechanism, as first explained by H. Le Chatelier in 1887, was that the hemihydrate $2CaSO_4, H_2O$ readily dissolved in water, the unstable solution being supersaturated as to the dihydrate (gypsum); any unburnt particles of the latter acted as nuclei for the crystallisation which was, as in supersaturated solutions generally, radial about the nucleus; the existence of the supersaturated solution had been proved by Marignac.

In the ordinary setting of plaster very little water was present, sufficient, however, to form the supersaturated solution and to deposit the dihydrate, the remaining water acting as resolvent. Against this explanation was only the view of Rohland [who died this autumn] that the salt took the water up in a colloidal form. The facts were not so simple, however, as just explained. Heat was evolved at two stages (Cloez), on mixing plaster with water and again later on. The density of the hemihydrate was 2.75, that of the dihydrate 2.32, so that a contraction of 7 per cent. should be observed, whilst an expansion took place, probably following a first contraction; owing to this expansion, which was, partly, rather a thrusting apart of the growing crystals than a proper expansion, plaster fitted the mould well and gave true casts. W. A. Davis had assumed other crystal modifications. The addition of other substances to the mortar might accelerate the setting (potassium sulphate), or

* Calcium sulphate $CaSO_4$ crystallises as such, without water (the mineral anhydrate), and as gypsum $CaSO_4 2H_2O$, and forms also other hydrates.

retard it (borax); Rohland found that the former increased, and the latter diminished the solubility of gypsum. Similar phenomena were observed with other supersaturated solutions, *e.g.*, sodium sulphate ($NaSO_4$, crystallised as Glauber salt with 10 H_2O), and also with solutions of metal oxides in their own salts. Zinc oxide, dissolved in zinc chloride, slowly crystallised as zinc oxychloride; in the similar case of magnesium oxide and chloride the chemical reactions were not quite certain. The orthosilicate of barium $BaSiO_4$ underwent hydrolysis with water yielding the metasilicate $BaSiO_3 6H_2O$ and barium hydrate, which set like plaster, but the product had not the strength of hydraulic cements.

Passing to lime mortars, composed only of slaked lime, sand and water, Dr. Desch remarked that they hardened by a mere process of desiccation. The calcium hydroxide might be colloidal or minutely crystalline; the sand merely prevented cracking during the contraction on drying by subdividing the lime into thin layers. As time went on, the hydroxide might recrystallise and the portions in contact with the atmosphere might be converted into crystalline carbonate; but neither of those changes was essential to the hardening, and there was no chemical reaction between the lime and sand. On the other hand when pozzolanic substances (volcanic earths) or burnt brick and ballast were added to the mortar, a chemical reaction between the lime and the active or soluble silica did take took place, and calcium metasilicate was formed.

Portland cement, Dr. Desch continued, was a more complex material. According to the brilliant investigations conducted at the Geophysical Laboratory—of which Mr. Rankin afterwards gave an account—five compounds might be present in that cement, two calcium silicates, two calcium aluminates, and free lime. Probably not more than three of these would be in equilibrium in the clinker; since, however, the temperature of the clinker was not allowed to reach fusion, they might all be present, though clinker made in a rotary kiln did not appear to depart widely from the equilibrium state. The equilibrium diagram showed the possibility of the existence of two ternary eutectics, which, Dr. Desch and Mr. Hattori had shown, were not directly visible owing to the minuteness of the structure, but became so on etching a polished section; the chief constituent of those eutectics, calcium aluminate, was in its finely-divided state very ready to react with water. The mechanism of this reaction and the setting process was, according to Le Chatelier—who also contributed a paper—a hydrolysis leading to the formation of (1) $CaSiO_3$, 2.5 H_2O, of (2) $4CaO$, Al_2O_3, 12 H_2O, and of calcium hydroxide. Microscopical examination showed the reactions to be strictly analogous to those of setting plaster; one had to bear in mind, however, that on a microscope slide much more water was available than in the gauging of cement. The alternative hypothesis of W. Michaelis assumed the same reactions, but different physical conditions. The metasilicate (1) was supposed to form, not a mass of radiating crystals, but a gelatinous mass (a gel), the gradual dehydration of which caused the hardening. The aluminate (2) crystallised more readily, but was also said to form a gel. The presence of a gel during the early stages of the setting, and the swelling by absorption of water had been proved by Stern and by Ambronn. R. J. Colony (1914) showed a subsequent reaction of the gel with the remaining constituents of the cement under formation of amorphous products (which hardened by desiccation) and also of zeolites. Keisermann had stained the various colloidal products and, though Dr. Desch had not confirmed all those results, such reactions depending on grain size, there were recent confirmations by Wetzel and by Blumenthal. The Bureau of Standards had also resorted to staining in their experiments on the setting of the individual constituents. They ascribed the initial setting to the hydration of the aluminates, $3CaO \cdot 1Al_2O_5$ and $5CaO \cdot 3Al_2O_5$; gelatinous alumina was also separated and the much slower hydration of the silicates might yield gelatinous silica. The subsequent crystallisation of the gelatinous compounds would, according to the Bureau of Standards, result, rather in a loss, than in a gain of strength.

The ratio of water to compounds was of the utmost importance in determining the particular nature of the products, though the chemical reactions might be the same, and hence microscope slide experiments should not indiscriminately be applied to practice. According to Weimarn, the passage from the colloidal to the crystalline state was continuous, the difference being one of size of particles. Colloidal materials might be in so fine a state of subdivision that the surface-forces became comparable to the mass effects; the degree of supersaturation might then determine whether the product separated in a crystalline form or in the amorphous form. Unfortunately the chemistry of colloids had been obscured by the barbarous terminology of Wolfgang Ostwald and others. As regards, finally, the action of catalysts on setting, Dr. Desch urged further research; the remarkable and technically important change in the velocity of setting observed when ground cement was stored, even out of contact with air, had not satisfactorily been explained yet.

Professor Henry Le Chatelier had entitled his contribution, "*Crystalloids against Colloids in the Theory of Cement*," and the first part of his paper was controversial. He had always opposed the theory which attributed the hardening of cements to certain colloidal properties of the materials, he wrote, as being devoid of sense. People evaded defining colloid, but seemed to take the word in the sense of being a body capable of hardening, and the explanation then came down to: cements harden because they have the property of hardening.'' Zsigmondy's ultra-microscope had shown that colloidal solutions were merely suspensions of very finely divided, rigorously insoluble matter. All insoluble bodies gave such suspensions; but was there any reason to give a particular name to particles, the only singular properties—terribly common-place properties—of which so far were insolubility and fineness? Those minute particles had one special important property, however, that of absorbing—"by snobbery one speaks of adsorbing now-a-days"—the bodies held in solution by the liquid with which they were wetted. That property the minutely-divided bodies shared with the porous bodies. The essential thing, of which chemistry did not speak as a rule, was the surface energy, measured by the product of the surface (or capillary) tension and the free surface. In the shape of a single sphere, which would have a diameter of 3.3 cm., and a surface area of 34 sq. cm., the surface energy of a gram-molecule (18 grammes) of water would be $34 \times 0.08 = 2.72$ gram. cm. (the surface tension being 0.08 grammes per linear centimetre) which corresponded to 6.3×10^{-3} kg. calorie. The vaporisation of a gram-molecule of water absorbed 10 calories, and its combination with lime liberated 10 calories; the surface energy was therefore only 1/100 millionth part of the latter quantity of heat. If, however, the single sphere were divided into a vast number of little globules, each of one millionth of a millimetre, their total surface energy would be 330 million times greater, and be equivalent to two calories, and thus of the order of the quantity of heat evolved by water in its various reactions. In the case of solids in suspension the surface tension at the contact between the solid and liquid could not be measured; but certain considerations suggested that the tension might become a hundred times greater than that of water, and its influence should be appreciable already for particles of dimensions far superior to those of chemical precipitates. These considerations also suggested the explanation of the usual insolubility of colloids. A solid crystal ground down to very fine grains would certainly have the properties of a colloid, as long as it retained its fineness; but it would rapidly lose the latter as soon as it was brought in contact with a liquid capable of dissolving the substance. The energy of dissolution would be increased by the whole surface energy of the crystal, and a supersaturated solution would result, from which crystals would be deposited. Every soluble body, even if existing in very fine division, progressively lost its colloidal properties when in contact with a liquid, in which it was somewhat soluble. It was only insoluble bodies, therefore, that could preserve the state of extreme subdivision corresponding to the colloid.

Professor Le Chatelier did not draw the conclusion that there is no clear distinction between colloids and crystalloids, since there is no absolute insolubility. Applying his considerations to plasters, however, he pointed out that, though the microscope had never disclosed any crystals in set plaster, they might yet be present, but too small to be visible. In the humid hydrated plaster crystals became visible in the course of weeks or days, especially when the plaster was gauged with alcoholic (instead of pure) water. The calcium aluminates of cements were hydrated at the same rate as plaster, and crystals of the hydrated aluminate could soon be seen when a few grains of the aluminate, instead of being gauged with little water, were placed in a large volume of water. On the other hand, calcium silicate would not give crystals of its hydrate, and that was his difficulty, since this silicate was the essential element in the hardening of Portland cement; but the analogous barium silicates did give such crystals, and the crystals of the much less soluble calcium silicate might be too small for visibility. He (Le Chatelier) had, moreover, shown that calcium silicate absorbed, in the moment of its formation, a certain amount of lime which did crystallise. Since the mechanical strength of the cement increased with time, the colloidal state, which was possible in the early stages only, had nothing to do with the hardening. As he had explained thirty years ago, the anhydrous compounds of cement were not in chemical equilibrium; they were more soluble in water than their own hydrates; they formed supersaturated solutions, from which crystals separated; the liquid being no longer saturated, could dissolve more anhydrous compound, and the whole mass passed through a stage of transitory dissolution in a limited volume of water which, at any given moment, could not maintain more than a small portion of the total compounds present. The crystals from supersaturated solutions were always elongated needles, grouped about the centres of crystallisation, and the entanglement of these crystals was the sole cause of the solidity of the mass. The crystals became welded with one another, friction at points of contact increased the resistance to mechanical separation, and the strength was that of tissues. The progressive growth of the crystal dimensions increased the part played by adhesion, while diminishing that due to friction; a material built up of very wide strips would be very solid if the strips were glued together at their contact surfaces.

Dr. H. Borns, who gave an abstract of the paper in the absence of its author, raised two objections. He did not understand how the considerations given explained the insolubility of colloids, and how the alternating progressive crystallisation and redissolution could go on in a solution which would remain saturated—not unsaturated, as Le Chatelier said—without some periodical factors of which there was no suggestion.

In his contribution on "*The Agglomeration of Granular Masses*," Professor F. G. Donnan, F.R.S., of University College, dealt with the broader problem of the agglomeration (caking, binding, setting) of granular masses (crystals, &c.) when immersed in a medium or wetted with it. A very small amount of this medium, an almost molecular layer of such a solution, would suffice to cause agglomerations. Professor Donnan said there were four principal factors causing agglomeration: (1) unequally divided stress. If the solid, but not the liquid, were submitted to stress, the solubility would increase, and the material dissolved would be precipitated again on contact with unstressed or less strained portions or granules of the solid; gravitation would suffice to produce such stress. (2) Unequal size of granules. Very small particles having a higher solubility than larger particles, the spaces between the larger granules were filled with the "fines"; the layer of solution on a fine particle then was not in equilibrium with the layer on a neighbouring larger particle, and re-solution and reprecipitation or recrystallisation occurred,

leading to the formation of cementing bridges and caking. (3) Existence of unstable or metastable forms. Unstable forms were generally more soluble than stable modifications, and as the former changed into the latter, re-solution and recrystallisation would be favoured. In the case of calcium sulphate Van 't Hoff had proved the existence of metastable forms. The case of ammonium nitrate, also referred to by Dr. Donnan, was afterwards mentioned again during the discussion. The reprecipitated or re-crystallised material might in all these cases be so finely granular as to be practically colloidal, and the colloidal state had, indeed, to be taken into account in all questions of setting. (4) Sheared or flowed crystal surfaces, what might be called the Beilby effect. Grinding and shearing would render the surface layers amorphous and hence more soluble.

(To be continued.)

NOTE.

SPARK PLUGS FOR HIGH-SPEED ENGINES.

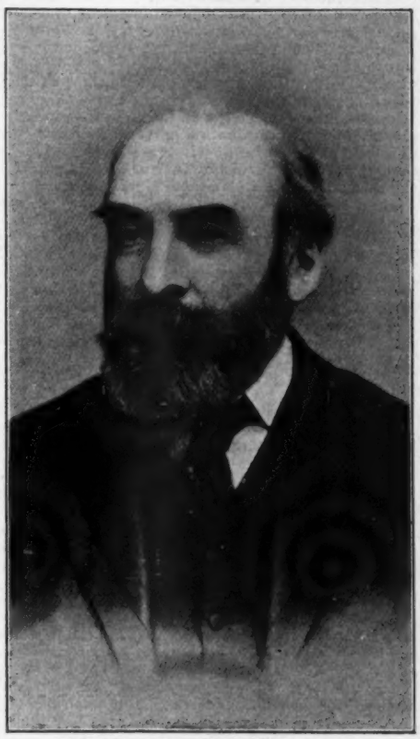
IN a paper contributed to the proceedings of the Society of Automobile Engineers (U.S.A) Mr. Albert Champion says that in the early days of the automobile there were no spark-plug makers in America, and motor car builders had to make their own, some used mica and some porcelain imported from France. A little later, France supplied most of the spark plugs used. When the manufacture was finally started in America the makers were very sanguine that they could produce soot-proof plugs, but even up to date it is, as Mr. Champion says, impossible to obtain plugs that will not soot under certain conditions, nor porcelain that will not ultimately crack. Owing to improvements in design there is, however, much less breakage with porcelain plugs than formerly. These failures were at one time laid to the door of the porcelain maker, but it was ultimately found that design had more to do with the trouble than the quality of the porcelain. The plain conical pattern as now made is superior to the petticoal type in the matter of keeping clear of soot. The conical porcelains are made of sufficient length and sufficiently small to get hot, and under these conditions they will soot less than the petticoal pattern which does not project so far into the combustion chamber and thus remains comparatively cool, a condition which favours the soot deposit and a consequent short circuit. The most suitable porcelain is made from a combination of English and French clays. The firing must be very carefully attended to. If the porcelain is underheated it will not withstand subsequent heating and cooling when in use, whilst if overburnt it blisters. A high di-electric strength is necessary as otherwise there will be a large leakage of current and a poor spark. Glass and quartz when hot are very inferior in this regard, and porcelains differ considerably in this qualification. As a consequence it is found that an engine can be throttled lower with one make of plug than it can with another of lower di-electric strength. All American made porcelain is, Mr. Champion says, prone to absorb carbon. No visible crack or break may appear, and hence the trouble with the engine may be attributed to other causes. French or Bohemian porcelain soots less than other makes, and as long as it does not crack the engine will run smoothly, and if sooting occurs, the plug will work well again after cleaning as the carbon is not absorbed. Pure nickel is, Mr. Champion considers, the best material for the central electrode, but that most commonly used is an alloy of nickel with 3 to 4 per cent. of manganese. The pure nickel, though otherwise advantageous, has, however, a higher coefficient of expansion than the alloy, and is thus more likely to crack the porcelain

THE PREPARATION OF FERRO-URANIUM:—ADDENDUM.—In the introduction to our article on Ferro-Uranium on page 41 of last week's issue, we stated that uranium had the highest atomic weight of any known element, viz., 237.77. This was the long-accepted figure, and we had intended to add that the recent revision—there has been no recent re-determination—of atomic weights yields the value 238.2. The difference is small, but not unimportant in so far as the adjustment made in the international table of atomic weights affects also radium and other elements.

THE LATE MR. FREDERIC ELIOT DUCKHAM.

MANY will share our regret upon learning of the death of Mr. Frederic Eliot Duckham, in his 77th year, at his residence, The Red House, Blackheath. Although it is twelve years since Mr. Duckham retired from active business, he is still well-known in engineering circles because of his ingenuity and inventive capacity. Of him it may be said that he was a born engineer, because in his boyhood his enjoyment was found among the Cornish mining machinery, and, in his youth, the study of engineering was a pastime, pursued with great perception, keen enthusiasm and full profit. In his later years, accumulated experience, combined with untramelled courage and sound commonsense, resulted in his overcoming many serious difficulties and evolving ingenious inventions. Simplicity, combined with admirable mechanical instinct, characterised his work, while by nature he was tolerant in the highest degree of the propositions of others which were to him always the subject of painstaking investigation.

Born at Falmouth, on June 15, 1841, the son of



MR. FREDERIC ELIOT DUCKHAM.

Mr. A. B. Duckham, shipping and Admiralty agent of that port—which throughout all vicissitudes has continued a calling place for shipping—he was early attracted to the problems of harbour work and loading and discharging facilities, but the local mining machinery still had for him the greatest interest. Family influence secured for him a place with the Electric Telegraph Company when he first came to London, at the age of thirteen years, and as he had, in his father's office, acquired some practice with the Morse code and needle instruments, he made great progress, which was, no doubt, stimulated by the receipt of cablegrams concerning the Crimean War.

About this time the Victoria Docks on the Thames were being constructed by the great contractors, Messrs. Peto, Brassey & Betts, and, in 1855, he entered their service, and took charge of the telegraph system installed for communication between the different departments of the dock works. There he came under what may be termed the influence of "hero worship" of some leading engineers, including Brunell and Latimer Clark, with the result that he devoted his spare time to the study of engineering. That this study was of profit is proved by the fact that in 1860, at the age of nineteen years, he constructed a model of a jetty, which, after being tested to destruction, was accepted as a design, and the resultant jetty continued in use until quite recently. He became Clerk of the Works for the general maintenance of the docks under the engineership of Mr. J. P. Bidder, and in this connection was employed on the building of the Victoria Graving Dock with hydraulic pontoons. Between 1862 and 1867 he was concerned in the construction of various interesting works in the neighbourhood of the Victoria Dock, and, his abilities having gained a wider recognition, he was employed on various other works, notably, the reconstruction of the Hertford Lock for the River Lea Commissioners, the building of the Gorleston Dry Dock, and some critical works at the River Nene, in connection with the North Level Outfall Sluice, when it showed some signs of giving way.

In 1868, at the age of 27, he was appointed engineer-in-chief of the Millwall Dock, a connection which was retained for nearly 40 years, during which period he was responsible for the spending of about three million sterling on equipment and maintenance. In the service of the dock authorities he steadily advanced, becoming, in 1899, the general manager, as well as engineer, holding the dual appointment until his retirement in 1905, when he was elected a director, a position he held until the property was taken over by the Port of London Authority. In addition to his dock duties, he carried out considerable important works, and was also the engineer for the construction of the old Thames steam ferry between Wapping and Rotherhithe.

In the earlier years of his connection with the Millwall Docks he carried out other undertakings, perhaps the most remarkable being that connected with the underpinning of the Town Hall at Yarmouth. The building had been erected, at very great cost, on ground which proved unsatisfactory in respect of foundations; one portion had sunk 18 ins. the clock tower being thrown considerably out of the perpendicular. By a system of underpinning with screw piles and steel girders he overcame the difficulties, and the paper which he read before the Institution of Civil Engineers on the subject created very considerable interest, not only for the boldness of his conception, but for the completeness of his success.

Perhaps, however, Mr. Duckham's name is best known because of his successful inventions. His weighing machine, which is familiar to most engineers, ensures economy in the double work of handling and weighing materials. His dredger, combined with the pneumatic discharge of spoil, first introduced at Millwall Docks, led to a great development in this branch of engineering, saving the Millwall Company £8,000 per annum. But more successful than any of these was his pneumatic grain elevator, first introduced at Millwall Dock in 1893, and installed at many other harbours. It was not only then an important development, but now, after nearly a quarter of a century, is of great national value in the quick discharge of grain in any weather, and with the minimum of labour. The extent of the application of these inventions was the more remarkable, as, owing to his exacting duties in connection with the Millwall Dock, he was precluded from giving that attention to their commercial extension which their engineering achievement thoroughly justified. The grain elevator, especially, was a triumph, associated as it was with all the desirable accessories—turn-over boxes, receiver, armadillo hose, and nozzle. He worked also at systems of handling timber cargoes. He was recognised as an expert in rating appeals, notably, in connection with docks and canals, and was engaged in connection with many of the negotiations associated with the promotion of the Manchester Ship Canal.

He became an Associate of the Institution of Civil Engineers in 1875, and three years later was elected a full member. His successive undertakings and inventions in engineering were dealt with in papers read before that Institution, and he was awarded the Telford Gold Medal and two premiums. He was a Vice-President of the Seamen's Hospital Society. During his long career, distinguished as it was by uprightness and combination of resource and simplicity, he earned the friendship of a very wide circle. Although he had acquired an exceptional intuition in engineering judgment, he was always restrained in personal criticism, and there are probably none who knew him whose regard will be other than that of friendly esteem. Since his retirement in 1905, his many old friends have continued to send him frequent tokens of their unvarying respect, a sound tribute to the unselfishness and sagacity of his professional life, and a great relief during his tedious affliction, so patiently borne.

In 1874, he married Maud Mary, daughter of Alexander McDougall, Manchester, and his three sons now occupy important positions at the Ministry of Munitions.

FUEL ECONOMY IN COOKERY.—A course of three lectures on "The Principles of Fuel Economy in the Design and Use of Cooking Appliances," will be delivered at University College, London, by Mr. A. H. Barker, B.A., B.Sc., on Wednesdays, January 23rd and 30th, and February 6th, at 7 p.m. The Lectures are open to the public without fee or ticket. Further particulars may be obtained on application (accompanied by a stamped addressed envelope) to the Secretary, University College, London (Gower-street, W.C.1).

INDUSTRIAL NOTES.

THE Cabinet decided last week that the settlement of any claim arising from the recent Orders granting an advance of 12½ per cent. to plain time workers in the shipbuilding and munitions trades shall be referred to the Ministry of Labour, in place of the War Cabinet Labour Committee. Following this decision, the Ministry of Labour received the following resolution in which the Minister of Munitions concurs: That this Committee of Trade Union representatives in the shipbuilding and engineering trades advising the Minister of Munitions request the Minister to represent to the Minister of Labour, who, they understand, is now charged with the settlement of the 12½ per cent. question, that the following should be the terms of settlement—(1) That the 12½ per cent. shall be extended to cover time workers who have not yet received the advance in the shipbuilding and munitions trades. (2) That so far as the pieceworkers in these trades are concerned no 12½ per cent. shall be given, but that low piece prices shall be revised, and that employers shall be given to understand that this is the decision of the Government.

The Minister of Labour proposes to deal with applications on the lines of this resolution, and under the procedure of the Munitions of War Act, 1915, Section I and Schedule I. The applications which have already been received by Government Departments are so numerous that it is almost impossible for settlement to be arrived at within the 21 days from the date of reference to the Ministry of Labour, but this need not cause any uneasiness in the minds of the officials of the trade unions or the workmen concerned. The Arbitration Tribunals have power to ante-date awards for such period as seems reasonable. The Minister of Labour urgently appeals to all concerned to exercise patience. It is the duty of all to continue to make the best effort. Stoppages of work will not help matters in the least, but will delay settlements. This statement is made with the concurrence of the representatives of the workmen in the trade unions chiefly concerned, and the Minister sincerely hopes that a willing response will be made.

Following upon a conference with the North-Western Engineering Employers' Association, the Secretary of the Engineering Trades Federation telegraphed last Friday, from Glasgow, to the Ministry of Labour and to the War Cabinet, as follows:—

"Representatives of the engineering trades employed in Glasgow and the West of Scotland, after a conference with the Engineering Employers' Association this afternoon, deplore that the offer of 6*s.* 9*d.* per week made by the Employers' Association is now superseded by the Order appearing in the morning newspapers and communicated to us by the employers.

"We desire to point out that while the situation was grave a week ago, it is now doubly so by this decision, in view of the fact that the offer now superseded has been in many cases remitted to the workmen and practically accepted.

"We think, therefore, that the offer of the employers here should be endorsed by the Government, thus averting a situation which will certainly lead to industrial disaster, and that within 48 hours."

The Ministry of Labour telegraphed last Saturday, in reply, stating the following:—

"Your telegram received. The Minister of Labour has decided to adopt the recommendations of the Trade Union Advisory Committee for the Shipbuilding and Engineering Industry as a basis for the settlement of all outstanding claims arising from the 12½ per cent. Order. All applications should be made through the Trade Union Executive who are the regular normal channels of communication between the Trade Unions and the Ministry of Labour. A stoppage of work is to be strongly deprecated. No application will be referred for settlement so long as a stoppage of work continues. The Minister is desirous of arriving at a settlement of these applications as quickly as possible and hopes to receive the ready assistance of all concerned." Signed: Shackleton, Secretary Ministry of Labour.

The War Priorities Committee was appointed some time ago by the War Cabinet to decide questions of priority of manufacture in their bearing on the conduct of the war. The composition of the Committee is as follows: Lieut.-Gen. the Right Hon. J. C. Smuts, K.C., Chairman; the First Lord of the Admiralty; the Secretary of State for War; the Minister of Munitions; the Minister of National Service; and the Air Minister.

The Committee is assisted in the conduct of its work by a Permanent Sub-Committee composed of representatives of the Admiralty, War Office, Ministry of Munitions, Air Ministry and Ministry of National Service. The requirements for war purposes of the various departments of the State are examined and co-ordinated by the War Priorities Committee, who decide the relative importance of their demands in accordance with the general rulings laid down by the War Cabinet, and arrange the allocation of the material resources and productive capacity of the country in the order of priority allotted. The War Priorities Committee performs its functions of allocation largely through the medium of Allocation Sub-Committees composed of representatives of the various consuming Departments concerned. These Sub-Committees have been set up by the War Priorities Committee to investigate with regard to specific materials, the supply available and the requirements of the several departments and public services and to allocate supply in accordance with the general priority laid down by the War Priorities Committee. Differences of opinion occurring within these Sub-Committees will be referred for settlement to the War Priorities Committee. In addition a sub-committee has been set up which deals with works of construction, both public and private.

In order that the requirements of the public services, such as transport, light, heat, power, &c., may receive proper consideration a general services committee has been appointed by the War Priorities Committee under the chairmanship of Mr. John Wormald, M.Inst.C.E., with representatives from the Ministry of Munitions, Admiralty, War Office, Board of Trade and Local Government Board. This Committee considers the requirements of these services and formulates on their behalf demands which are taken into account by the War Priorities Committee in their allocation of the available supplies of the various commodities. The Chairman of this Committee is assisted by an Advisory Committee whose particular duty it is to inquire into the needs of the various general industries, the maintenance of which is not vital to the supply of war material or to the life of the community, but which it is desirable to preserve, if such preservation can be secured without sacrificing interests deemed essential to the successful prosecution of the war. The composition of this Advisory Committee is the following: Mr. George E. Alexander; Mr. Kenneth Chance; Sir Archibald Denny, Bart.; Mr. Alexander Walker; Mr. Henry Woodall, M.Inst.C.E.; and a representative of the Board of Trade.

The Secretary of the War Priorities Committee is Colonel F. J. Byrne, C.M.G., with offices at 11, Pall Mall, S.W. Applications for Priority Certificates and Permits should continue to be sent to the Priority Departments of the Admiralty and Ministry of Munitions.

An appeal under Section 3 of the Munitions Act, 1917, was made last week in the Glasgow Local Munitions Tribunal, by a firm of Clyde shipbuilders, to determine whether riveters employed on contract work were entitled to a week's notice before dismissal. The local tribunal found that the men were entitled to the week's notice.

In the course of his speech in the House of Commons last Monday, introducing his combing-out Bill, which was then read for the first time, Sir Auckland Geddes stated that the men to be withdrawn from industry during the next two or three months, for service in the army, come under the three following classes:—

A.—Men under 24 years of age who are fit for general service (Grade 1), with the exception of a few classes of men engaged on ship construction and repair.

B.—Men fit for general service up to a higher age than 24 engaged on certain kinds of work which can be done after a short period of training by men above military age, or otherwise unfit for military service, discharged soldiers, or women.

C.—Men fit for general service who have entered war industries since August 15, 1915, except in certain departments of aircraft production and a few small industries which have been set up since 1915.

The Director of the Department of Labour Statistics, writing on the state of the Labour Market in *The Labour Gazette*, says that employment continued good in December in nearly all the principal industries, and in many of them inadequate staffs worked much overtime to meet Government requirements. Shortages of materials caused some unemployment, especially in the cotton trade, which, together with the woollen and worsted industries, continued to be directly affected by the Orders restricting consumption.

The changes in rates of wages (including war bonuses) reported to the Department as taking effect in December affected over 1,800,000 workpeople, and resulted in a total increase of nearly £380,000 per week. Male workpeople in the engineering and shipbuilding trades received increases of 5*s.* per week for men and 2*s.* 6*d.* per week for boys, bringing the minimum war increase for men up to 20*s.* per week. Large numbers of workpeople in other metal industries received similar advances. There has also been an extension of the bonus of 12½ per cent. previously granted to skilled engineers and moulders employed at time rates, on munitions work, to certain other classes of munition workers on time rates. Other important increases granted during the month affected workpeople in the cotton industry, and hosiery workers in the Midlands.

The number of disputes beginning in December was 40, and the total number of workpeople involved in all disputes in progress was 26,736, as compared with 239,253 in the previous month, and 36,627 in December, 1916. The estimated total aggregate duration of all disputes during the month was 158,000 days, as compared with 997,900 days in November, 1917, and 157,300 days in December, 1916.

The average weekly number of vacancies notified to all Employment Exchanges for the four weeks ended December 7, 1917, was 40,851, as compared with 43,284 in the previous four weeks, and with 39,762 in the four weeks ended December 8, 1916. The average weekly number of vacancies filled for the same periods was 30,322, 32,166 and 30,405 respectively. The numbers of workpeople remaining on the live registers at December 7 were 29,282 men, 56,643 women, and 14,976 boys and girls, a total of 100,901.

Mr. G. N. Barnes, M.P., Labour Member of the War Cabinet, speaking last Tuesday at the Glasgow Rotary Club, said that, following the abolition of leaving certificates, Mr. Churchill made himself responsible for dealing with an anomaly. Some highly-skilled men had been working for comparatively low wages, as compared with the high wages of some operatives who had come into certain trades and were working on piece-rates. Mr. Churchill, probably, did not know, Mr. Barnes added, that that anomaly had been very largely adjusted by other means. Employers and highly-skilled men, in a spirit of mutual goodwill, had come together and had largely adjusted their own difficulties. Mr. Churchill was not aware of the fact, and made a promise that, in abolishing the leaving certificates, he would give an increase to the particular class of men in question. Mr. Churchill had in his mind only a very small number of operatives, a few thousands probably, and when practical men came to look at the problem they found that this increase in wages could by no possible means be made to apply to that small body of operatives alone. When Mr. Churchill "butted-in" with the new principle of giving 12½ per cent. to time-workers on the top of the scale among the mechanics, it was found impossible to prevent that 12½ per cent. going right down the scale, and applying to all time-workers, labourers, semi-skilled and skilled men. That brought the Government up against the difficulties they had been in during the last few weeks, and they had been living on the top of a veritable volcano.

If he, Mr. Barnes, had been a dictator at the beginning of the war, he would have paid workmen according to results. If they wanted more money, they would have to produce more goods. Mr. Churchill's order was absolutely against that principle; instead of encouraging men to work by results, it encouraged them to go on the old lackadaisical system of working by time. The time fetish was a stupid fetish, whilst piece-work gave a man an added interest in his work. During war pressure, to encourage time-workers and discourage piece-workers was lamentable. He asked the piece-workers to be patient, "and we will see," he added, "that the 12½ per cent. given to the time-workers will be given to the piece-workers, with due regard, however, to the earnings of those piece-workers at the present time."

In a speech in Parliament last Wednesday, Mr. Barnes added an explanation to the effect that he had no intention of disclaiming responsibility for the course taken by the Government in regard to the 12½ per cent. advance. What he ought to have said at Glasgow, he added, was "we butted-in. . . ."

TRADING WITH THE ENEMY ACT.—The Controller of the Foreign Trade Department has sent us a copy of a new list (No. 44) of additions to the Statutory List of firms of enemy nationality or enemy associations with whom persons in the United Kingdom are forbidden to trade. Copies of this list can be obtained at a trifling cost from the Superintendent of Publications, H.M. Stationery Office, Imperial House, Kingsway, W.C.

THE LATE MR. JOSEPH BARROW.—We regret to record the death at Disley Mount, Northwood, Middlesex, in his eighty-seventh year, of Mr. Joseph Barrow, of the firm of Messrs. Thomas Shanks and Co., of Johnstone. Mr. Barrow, in his earlier days, was long connected with the then firm of Smith, Beacock and Tannett, of Leeds, who held a high position as makers of machine tools and had a large connection among the leading railway companies. Mr. Barrow himself gave much attention to the design of machines for producing large screws, such as those used in screw couplings, &c., and a large number of these machines are in use. Later, as stated above, Mr. Barrow joined the firm of Messrs. Thomas Shanks and Co. He was elected a member of the Institution of Mechanical Engineers as long ago as 1862, and for very many years he was one of the most constant attendants at the summer meetings. Mr. Barrow had a very wide circle of friends among mechanical engineers of all classes and his death will be much regretted.

THE OPTICAL SOCIETY.

AT a meeting of the Optical Society, held at the Imperial College of Science and Technology on the 10th inst., the President, Professor Frederic Cheshire, C.B.E., in the chair, a paper on "*Relative Dispersion and Achromatism*," by Mr. Francis E. Lamplough, M.A., and Miss J. M. Mathews, was read and discussed. It contained an account of an inquiry into the extent of the relation between the irrationality of dispersion in glasses and the mean dispersion and dispersive power. The work consisted chiefly in the reduction of observations made by Lieut.-Col. J. W. Gifford on the refractive indices of 13 spectral lines for 30 glasses. The results showed the absence of any accurate relations. It was found that in general the type of dispersion of glass is determined by its dispersive power, but with a few special glasses, mostly requiring protection, an improvement could be effected on the achromatism secured by ordinary glasses of similar dispersive power. The problem of the triple objective was referred to. Mr. H. S. Ryland exhibited a Galilean binocular designed for increasing the field of view.

A communication entitled "*A Spherometer of Precision*," was presented by Mr. J. Guild, A.R.C.Sc., of the National Physical Laboratory, describing an instrument which he had designed. It was exhibited at the meeting. The chief feature of this instrument is the method employed for detecting the exact contact between the micrometer screw and the surface under test. The micrometer terminates in a small sphere of about 1.5 mm. diameter. A microscope with a suitable illuminating apparatus is mounted above, and the Newton's rings surrounding the point of contact are observed. By watching the behaviour of the rings when the screw is brought up, the exact point of contact is determined. The sensitivity is about one ten-thousandth of a millimetre.

With reference to the papers on "*Optical Standards and Nomenclature*," by Mr. J. W. French and Mr. T. Smith, which had been read at the previous meeting, it was resolved that the proposals therein contained be referred to the Council of the society with the recommendation for the appointment of a committee to consider and report upon them in due course.

The President announced that the proposal for the formation of a new class of members to be denominated "Fellows" would be put before the society at an extraordinary meeting, to be held on February 14.

CHEMICAL CONSTITUTION AND PHYSIOLOGICAL ACTION.—We hear so much of the triumphs of chemistry and of the successful preparation of new dyes, which show the properties they were intended to have, and we are so impressed with the virtues of aspirin and similar synthetic drugs, that we are apt to assume that physiological chemistry, which certainly does not lack able and devoted workers, will have been equally successful. When, in December last, Dr. Frank Lee Pyman lectured before the Chemical Society, on the "Relations Between Chemical Constitution and Physiological Action," however, he had to admit that not one of the natural compounds, like quinine, which chemists have been attempting to modify, is surpassed in its characteristic effects by its artificial derivatives. Though it had been possible to prepare some derivatives or synthetic analogues which had proved to be of service in medicine by eliminating secondary effects, science had hardly improved upon naturally-occurring active principles. In such researches the active principle is first isolated, *e.g.*, the compound which stops fever, the quinine, is extracted from the bark of the cinchona tree; this principle is then studied by analytical and synthetic methods; the constitution of the quinine having been established, characteristic groups or radicles of the molecule are replaced by others in order to ascertain on which groups the activity seems chiefly to depend. That is, of course, the most difficult part of the research; the living organism is so complicated a system that it is rarely possible to connect effect and cause in any definite way. As a result, the relation between constitution and physiological action remains obscure. In the case of dyes, a single physical property, the absorption of light of a particular wave-length, has to be studied, in the first instance at any rate. In physiology there is generally no striking criterion; the same superficial action may, apparently, be due to different causes. Dr. Pyman, who is working in the Wellcome Research Laboratory, one of the most noteworthy institutes of its type, dealt in particular with quinine and emetine (remedies to kill the plasmodia of malaria and to cure amœbic dysentery), the tropeines (atropine, hyoscyamine, &c., which enlarge the pupil of the eye), cocaine (an anæsthetic), and adrenaline (which excites sympathetic nerves, and raises the blood pressure). Hundreds of experiments, taking the molecules of these compounds to pieces, so to say, and building them up again by systematic substitutions, have been crowned with little success. Sometimes an effect was intensified by passing to higher homologues, or other groups. But it was mostly very difficult to discover the really characteristic groups; quite different groupings may, apparently, have similar effects, and the real physiological actions, why and how the compounds act on nerve-endings and other organs, are not understood. Frequently stereoisomerides, *i.e.*, substances, the constitutions of which differ merely as much as an object and its mirror image differ, have greatly different effects. Possibly, physiological tests, with all their uncertainty and suffering, are occasionally resorted to before the agents have properly been studied as to solubility, diffusibility and other properties; the speakers during the discussion agreed that the basis of these researches should be broadened.

COLONIAL ENGINEERING PROJECTS.

WE give below a few data on several Colonial engineering projects, taken from *The Board of Trade Journal*. Further information on these projects can be obtained from the Department of Commercial Intelligence, 73, Basinghall-street, London, E.C.2.

Australia.—The Imperial Trade Correspondent at Adelaide reports that among the public works likely to be undertaken in South Australia are the following:—It is proposed to build a large reservoir on the Tod River, near Port Lincoln, to supply settlers on Eyre's Peninsula. It will be a very large undertaking, with trunk mains, and pumping appliances to raise water to a sufficient height for gravitation. The Barossa Reservoir, with earthen embankment and many miles of trunk mains, will probably require only a small amount of imported material. The Monarto-Palmer Railway, about 27 miles, of 5-ft. 3-in. gauge, and the Palmer-Sedan Railway, about 15 miles, of 5-ft. 3-in. gauge, have obtained the requisite rails in the Commonwealth. A floating dock and coal-handling plant are to be established at Port Adelaide. The foregoing works have all practically been decided upon, but they will not be proceeded with until money to carry them out is available, and it is probable that some considerable time will elapse before any of them are started. The following Railway Bills are before Parliament at present:—Hanson-North Booborowie line, about 24 miles, 5-ft. 3-in. gauge; Willunga-Yankalilla Railway, 23 miles, 5-ft. 3-in. gauge; Wandana-Penong Railway, 54 miles, 3-ft. 6-in. gauge; and the Long Plains-Red Hill Railway, 61 miles. It is also proposed to broaden the gauges on the North-Western system, at an estimated cost (exclusive of rolling stock) of 621,000*l.* The question of carrying out construction work on these proposed railways will be decided very shortly. In all probability, adds the Imperial Trade Correspondent, the rails for any new railways will be obtained in the Commonwealth, but it will be necessary to import accessories.

New Zealand.—In the Annual Statement for 1917 by the Minister of Railways, reference is made to a new type of locomotive which is now being employed on the railways of the Dominion. The engines are simple superheated tender engines of the Pacific type, built in New Zealand. It is anticipated that having been adopted as a standard type, the engines, which are known as Class AB, will cost at least 1,000*l.* less to build per engine than the Class A four-cylinder compound passenger-engine which the AB type is designed to replace. The new type, it is stated, has proved itself 20 per cent. more economical than the Class A type in the consumption of coal and water, whilst hauling considerably increased loads on express trains in the South Island. The engine is also more convenient for repairs on the road, and it is anticipated that it will be considerably less costly to maintain. United Kingdom locomotive builders should watch the New Zealand market, and not take for granted that the locomotive business in the Dominion will be restricted to its own home industry.

GERMAN TRADE AFTER THE WAR.—To those who imagine that Germany will return to the competition with her old fierceness and success, and that, in spite of the disrespect she has created, she will beat us by offering her goods at prices we cannot touch, it may be pointed out, says *The Marine Journal*, New York, that German progress in the past has been due largely, if not mainly, to a set of artificial factors and forces that can hardly exist after the war. It may be said that the very mainspring of German competition has been subsidisation, and for decades, if not for generations, German finances will not be in a state to afford the lavish subsidising of exports that characterised the competition of the last fifteen years before the war. Not only will German industries lose about 2,000,000 of their men, but they will lose the generous State subsidies, bankers' credits and syndicate bounties which have hitherto enabled them to sell their goods abroad so cheaply.

TRANSMISSION OF COKE-OVEN GAS IN SILESIA.—Since 1911 coke-oven gas has been supplied from the coking plant near the Julius Colliery to Waldenburg and other places in Silesia, and the transmission and distribution lines have considerably been extended of late. Two short lines, about 2 miles long each, start from the colliery, the one to Waldenburg, the other to the gas-holder and general gas-meter stations at Altwasser; the mains have diameters of 200 mm. and 150 mm. The soil on the latter line is so much subjected to subsidences that it was not considered advisable to bury that section of the line in the ground; staging was first considered, but finally the line was laid in the ground. The line consists of steel pipe sections, 10 m. or 12 m. in length, and in the endangered ground the ends of the sections (Mannesmann pipes in this part) were fitted into curved sleeves; in some cases the pipe was pulled 400 mm. out of its sleeve, the subsidence of the ground amounting to quite 1 m. in the course of a year. The supply of gas was only in one case interrupted for more than 3 hours, however; the gas losses in the pipe system range from 2 per cent. to 8 per cent.; they are generally highest in the beginning of the summer (*Journal für Gasbeleuchtung*, October 27, 1917). In the gasholder the pressure is high, but in the distributing pipes it is 175 mm., 150 mm. or 80 mm. The coke-oven gas having a higher density than the coal gas formerly used for illumination, the gas pressure had to be adapted to the burners. Some of the high-pressure mains are more than 40 km. in length. The gas supply had, by 1916, increased to 5,000,000 cub. m. per year, but the industrial use of gas in large works was only developing.

FUEL OIL.

TO THE EDITOR OF ENGINEERING.

SIR,—War has to some extent familiarised the public with the term fuel oil, more especially with regard to its use in the Navy, but there are a great number of industrial concerns, &c., engaged on turning out munitions of war where the use of fuel oil is of the greatest possible help, as in a well-designed furnace and a proper system of oil-burning apparatus the work done is often as much as three times the work of coal, pound for pound, whilst the heat generated is uniform, and can be governed to a nicety, and the rate of output of finished material is vastly increased.

The term fuel oil is generally applied to the petroleums, but necessity and opportunity has brought about the use of other liquid hydrocarbons, and among the liquid fuels which can be made use of may be mentioned petroleum, whether crude, residuum, or pure, coal tar, water-gas tar, mond-gas tar, creosote, blast-furnace oil, coke-oven oil, alcohol (crude rum), castor oil, rape oil, cotton-seed oil, cocoanut oil, &c.

Pitch can be made available for fuel for industrial process furnaces if mixed with a suitable proportion of creosote, and all of the tars, pitches and creosote may be used with advantage in the speeding-up of forgings, castings, and other material needed for war. Low-grade tin ore, copper ore, or zinc ore can be successfully treated with the aid of liquid fuel, where the same ores would not pay if treated with coal.

Prior to the war, and since then, many firms have been simply turning valuable liquid hydrocarbons into the sewers, or rivers, without in the least knowing that these had a value both as a fuel and for other purposes, and the fullest advantage should be taken of possible distillations from the valuable dross (so-called) which is to be found on the waste heaps of England in the form of cannel coal.

It would not pay to import rape oil, cotton-seed oil, castor oil, alcohol, and the like, to be used as fuel, but it would help to save tonnage if some of our distant colonies used such material as fuel instead of importing coal from England.

At the present moment the power to produce rapidly far outweighs the cost of fuel, if that is a consideration. The fact is that an oil-fired furnace (in my experience) will do vastly more work in a given time than fired with coal or coke—seldom less than twice as much, and often thrice as much. Thus the business man who runs a brass foundry, for instance, has to consider not merely the relative cost of oil *versus* coal, but whether the power to avail himself of the casting floor at least twice as often, and thus double his output of finished goods, does not outweigh any consideration of cost of fuel. This applies with truth in every case where process furnaces are employed for melting, forging, hardening, annealing, and the like.

Liquid fuel can be employed as an economical substitute for coal in almost every industry where power or heat is required; a few of the advantages to be gained are as follows:—

Weight for weight, the calorific value of liquid fuel as compared with best average Welsh steam coal, is about 14 to 9, or, in other words, 9 tons of liquid fuel will evaporate the same quantity of water as 14 tons of coal: in addition to this obvious economy, it is possible to obtain 83 per cent. of the calorific value of the liquid fuel used, whereas with coal a larger proportion of the fuel passes away unconsumed in the form of smoke and soot. With liquid fuel none is lost from start to finish.

With ordinary care there is no visible smoke in burning liquid fuel, thus making for cleaner and healthier conditions and causing a further economy, as no labour is required for removing ashes and clinker. Weight for weight, liquid fuel occupies only about five-eighths of the space required for coal; it can be stored in places inaccessible for coal storage, thus making use of space which would otherwise be wasted.

Fires can be readily started and instantly stopped: the burner may be only just alight or increased to full flame, thus high pressure can be rapidly obtained, and a steady head of steam maintained without waste, and there are no "stand-by" losses. To-day it is possible to conceal the presence of a warship using oil fuel by steaming without smoke. When, on the other hand, there is need for concealment it is possible instantly to create a veil of smoke sufficiently dense to shut out the vessel from view of the enemy.

Both uses of the oil jets have been used successfully in the North Sea fight. The cleaning of fires in a warship or merchant ship will account for a considerable loss of power for one hour out of every four, and this has been estimated in fast ships to be not less than 10 per cent. Where oil is used as an auxiliary to coal (in the cruisers and the battleships) steam can be maintained regularly at full power during the operation of burning down and cleansing fires, so that the ships are ever ready and always at full power, ready to meet any demand on them, whether to give battle or the reverse.

Demands for speed can be met instantly where oil fuel is used, whereas where coal is used time must elapse (vital time) before the fires can be quickened to meet an urgent call. Where oil fuel is used solely the fires can be eased down instantly, and in the case of loss of feed water in the boiler, or in the case of the boiler being injured by shot or shell, the fires can be instantly extinguished by shutting off the oil supply by means of a control valve. Oil fuel under destroyer conditions makes for safety of boiler and crew. Further, it suffers no deterioration from long storage.

Naval ships of the largest class find that the adoption of oil fuel enables spaces hitherto unused to be utilised for the storage of oil, for instance, the double-bottom peak tanks, or spaces altogether too narrow to admit

of coal being easily got at. More fuel, too, can be taken aboard in an hour from a "tanker" than the whole ship's company could handle in 12 hours when coaling.

Owing to the great demand for oil fuel for warships, &c., and the comparative scarcity of tank steamers, there is no reason whatever why double-bottomed ships which use the double bottom solely for water ballast when eastward or westward bound, should not use the space for carrying oil fuel in place of water when returning from the United States with grain and cotton or other light cargoes. This would mean dividend-earning as well as speeding-up the delivery of much-needed oil fuel, and this might also make for the lowering in price of oil through the cheaper means of transit by pressing into the service vessels which are not specially constructed with holds to carry oil in bulk. Oil is cheaper to use than coal anywhere east of Port Said.

Nothing, to my mind, is too trivial to consider at the present moment, if it will count in the game of winning both in a military sense and in the industries.

Yours faithfully,

J. J. KERMODE, M.I.Mech.E.

35, The Temple, Dale-street, Liverpool,
January 1, 1918.

THE VALUE OF SUPERHEATING IN LOCOMOTIVES.

TO THE EDITOR, ENGINEERING.

SIR,—The letter by "Loco," in your issue of January 11 is, so far as I am aware, the first reasoned attempt to answer at any length certain remarks by Mr. C. R. King, in the discussion at the Institution of Civil Engineers on Superheating in Locomotives. The letter does not, however, seem to me to deal with Mr. King's suggestion that, other things being equal, an absolutely fair comparison can only be made between two engines *of the same total weight.*

For this purpose, taking the basis experimental engine the saturated boiler should first be increased by an amount equivalent to the increase in weight due to the fitting of the superheater on the competing engine. Your correspondent states that this increase is apt to be over-rated, and he gives the net addition to the *boiler only* as amounting in a particular case to rather more than half a ton. But other increases in weight are usually involved, by larger cylinders, and more or less elaborate arrangements for damping, circulating, &c., though these vary considerably and their constant changes in principle and form show that these accessories are still in the experimental stage. Many of the elaborate arrangements adopted appear to have only a short life.

Referring to the figures given by Mr. Fowler for the Midland locos. on trial, it will be found that the difference between engines Nos. 992 and 998 amounts to over two tons; between engines Nos. 1040 and 1039 to over 1¼ tons, but between engines Nos. 484 and 489 to less than ¼ ton.

It seems to be generally agreed that the Super-heater shows to greatest advantage when the boiler is being forced—in other words the saturated steam boiler is at a disadvantage under such conditions. Now a boiler is forced when it is being fired at a higher rate than that for which it is designed.

Is it not fair to conclude that had advantage been taken in one case, of the two tons required for fitting a superheater to put in a by so much larger saturated boiler, the latter might have economically satisfied a higher demand upon it, and a more just comparison with the superheated boiler would have been possible taking the engine as a whole. So far as I am aware no such comparison has been made in practice.

As regards Mr. King's contention that a superheated engine is—other things being equal—less powerful, I have lately observed a tendency in railway practice to return to higher boiler pressures, while at the same time retaining larger cylinders for use with superheated steam. In conclusion, I feel that Mr. King's objections have never been fairly answered by those who are in the position to carry out comparative trials on the lines above indicated.

Yours faithfully,

"LOCO. M.I.M.E."

January 15, 1918.

TO THE EDITOR OF ENGINEERING.

SIR,—The letter from "Loco." in your impression of the 11th inst., raises one or two points in relation to boiler efficiency, which I think might, with advantage, be further discussed.

The instance mentioned of the 4-4-0 engine having its tube surface reduced by plugging is very interesting, but it is, in my opinion, open to question whether the same experiment, carried out rather differently, might not have yielded even more surprising results. For, the tubes being plugged, not only was the nominal heating surface rendered of no avail, but the whole space occupied by the tube was useless. Now, had the reduction of tube surface been effected by removal of the tubes, we should, I think, have seen that the reduction could have been carried much further; for the space formerly occupied by the tubes would then have been filled with hot water—a potential source of power entirely absent in the experiment as carried out. This, of course, would constitute, in a modest way, thermal storage, which I venture to think, is of much greater value than nominal heating surface in tubes. I am led to this conclusion from observation of the working of the boilers used by the brothers Stirling in their locomotives, which, generally speaking, though meagrely supplied with tubes, as compared with those of their contemporaries, were remarkably successful on the road. For this reason I, for one, am not surprised at the success of the superheated boiler, despite its lesser number and surface of tubes.

Your correspondent further states that the quantity of steam produced is proportional to the heating surface. This is hardly borne out by facts. I remember some boilers being built by one of our great lines, which were plentifully supplied with heating surface, but which never suffered from excess of steam production when it was needed most! In fact, it was in this respect that they conspicuously failed—their barrels simply reeking with tubes, to such an extent as to impede circulation pretty effectively. It would appear that there is a critical proportion of the cross-sectional area of a boiler barrel which may be legitimately occupied by tubes, any material variation from which will reduce the efficiency of the boiler and this I beg to suggest would be a fruitful field for study and experimental investigation, which, as far as I am aware, has not received the attention it deserves.

I trust that "Loco's." letter will be productive of a valuable and instructive discussion, the subject being by no means exhausted.

Yours truly,

A. J. BREWER.

London, E.C., January 16, 1918.

THE REPAIRS OF HEAVY CASTINGS BY WELDING.

TO THE EDITOR OF ENGINEERING.

SIR,—I have read, with much interest, the article in your issue of 11th inst., describing the repairs by oxy-acetylene, and electric welding, to the machinery of the German ships seized in America.

I enclose herewith photograph of a repair to colliery pumps, weighing 2 tons 12 cwts., in which a corner was

broken off and repaired by oxy-acetylene welding. The metal, in this case, ranged from 2½ in. to 3½ in. in thickness.

I also enclose a photograph of a casing, about 10 ft. in diameter, which was repaired by oxy-acetylene.

I do not think it is generally known that repairs of this weight have been effected in this country, and, I believe, this would prove of general interest to engineers.

Yours faithfully,

(For Oxy-Acetylene Welding Company, Limited),
J. BROWN.

169, Finnieston-street, Glasgow, January 15, 1918.

[We reproduce herewith the photograph of the heavy colliery pump casting referred to in the above letter.—ED. E.]

THE PRODUCTION OF DUCTILE TUNGSTEN.

TO THE EDITOR OF ENGINEERING.

SIR,—As solicitors for Messrs. Duram, Limited, the well-known manufacturers of ductile tungsten for filament lamps and other purposes, our attention has been called to the letter of Mr. John Gray, in your issue of December 28, and to his statement that "British Thomson-Houston Company were supplying their whole requirements of ductile tungsten for Mazda lamp filaments in 1912 by manufacture at their Rugby works."

Mr. Gray's statement will be received, no doubt, with amusement by many lamp manufacturers in this country, but there is really no excuse for the inaccuracy of his statement, inasmuch as Mr. Frazer, the Secretary of the British Thomson-Houston Company, in an affidavit filed by him in the action brought by that company against Messrs. Duram, Limited, for infringement of their patent No. 21,513, of 1906, which action was dismissed by Mr. Justice Astbury and the Court of Appeal, swore that between October 1, 1912, and September 30, 1913, the total production of tungsten wire drawn at Rugby, as evidenced by the production sheets, was 5,835,686 ft.; of which more than two-thirds—viz., 3,824,247 ft.—were drawn from tungsten rods and coarse wire imported from the General Electric Company, of America.

The total production of finished wire manufactured and drawn in its entirety at Rugby was only 2,011,839 ft., and the value of much of that for lamp-making purposes can be appreciated, since the production sheets show that quantities of this were in lengths of less than 100 ft.

Allowing for wastage only 20 per cent., which would be very generous at that date, and allowing 3 ft. to a lamp, the British Thomson-Houston Company only made wire in its entirety for 536,490 Mazda lamps during the period mentioned. It will, in addition, be noted that this period includes nine months of 1913, whereas Mr. Gray speaks of 1912, when his company could hardly have been more successful.

Having had his attention called to the matter, Mr. Gray would not wish us to omit to notice that the secretary also admitted the importation of lamps from America during the same period.

Having proved the inaccuracy of Mr. Gray's statement we may be permitted to add that our clients, Messrs. Duram, Limited, are, and have for some time past been, manufacturing millions of metres of drawn tungsten wire at Hanwell, which would go far towards supplying the whole of the requirements of the United Kingdom.

Yours faithfully,

SPEECHLY, MUMFORD AND CRAIG,

10, New Square, Lincoln's Inn, W.C. 2.
January 15, 1918.

CONCRETE COTTAGES.

TO THE EDITOR OF ENGINEERING.

SIR,—Your correspondent "Philadelphian" is hardly fair to concrete as a material for workmen's dwellings in his letter of January 4. He says that concrete has been tried and has proved a failure because (*a*) concrete houses are very cold, (*b*) they have excessive and incurable condensation internally, (*c*) they are costly to build, (*d*) they are costly to maintain, (*e*) concrete materials are dear, scarce and costly in transit.

Taking these in order (*a*) there is scarcely any difference between thermal conductivity of concrete and brick; hollow concrete building bricks are extensively used for high-class dwelling-houses in the States, and have been proved to be cool in summer and warm in winter.

(*b*) Condensation is caused primarily by difference of temperature between walls and air; it may occur on painted walls in the best-class of house; by casting the interior surface of a concrete house in coke-breeze concrete or, alternatively, by plastering the walls with a fibrous plastering material, it can be entirely prevented.

(*c*) The cost of concrete in place depends on the method of handling it; the latest and most up-to-date method dispenses very largely with timber or steel shutters and uses a form of mould and method of handling which brings the cost to a minimum; under these methods a shell 60 ft. by 25 ft. by 20 ft. high, roofed and floored, with hollow concrete walls having 3 in. air space, would cost considerably less than 300*l.*; when made it would be a monolithic structure almost capable of being picked up by a crane and dumped down anywhere, like an iron casting.

(*d*) There should be absolutely no maintenance in a well-designed concrete building; concrete is a homogeneous material usually made from the hardest gravel flint which has been knocked about in river beds for tens of centuries, united by a cementing material of high tensile strength and very high compressive strength; it is a remarkable thing about concrete that its strength grows from year to year, and it is doubtful if laboratory experiments have yet revealed the age when concrete acquires its maximum strength. Concrete buildings require neither painting nor pointing, but brick block structures require a great deal of the latter in the course of years.

(*e*) Concrete materials, in the shape of stone and sand, are very widely distributed everywhere; a glance at a geological map would show if clay for bricks, or rock or gravel for concrete, were the more widely distributed. Cement is manufactured in nearly every district in England, and only 5 cwt. is required per cubic yard of concrete or, say, 25 tons for the concrete shell just mentioned; the cost of freight is not a serious matter.

We would not be inclined to consider that a roof made of hollow bricks reinforced with steel would keep watertight very long; it would probably need an asphalt coating at a cost of 10*s.* per yard superficial, or, say, 80*l.* total for the shell building above mentioned, whereas concrete properly cast is perfectly watertight when used as a floor or roofing slab. Further, flat concrete roofs for cottage outbuildings could be readily turned into rain-water tanks, which could not be done with any form of brick blocks.

We would not be inclined to recommend steel sashes with leaded lights; leaded lights are a luxury for the very highest class of residential houses, except, of course, for stained glass windows, which are not often cleaned.

Yours faithfully,

(Trent Concrete, Limited),
G. SARGENT, Chief Engineer.

THE LATE MR. WILLOUGHBY ROCHESTER HUGHES.—We regret to have to announce the death, which occurred on the 11th inst., at Newchwang, North China, of Mr. Willoughby Rochester Hughes, Engineer-in-Chief of the Liao River Conservancy. Mr. Hughes entered the Institution of Civil Engineers in 1878, and was appointed a full member on February 11, 1908. He was 65 years of age.

SOME UNUSUAL FEATURES IN THE MICROSTRUCTURE OF WROUGHT IRON.*

By HENRY S. RAWDON.

I. INTRODUCTION.

The structure of wrought iron as usually described by metallographists and workers in metal is that of a fairly pure iron. Impurities, if present, are usually considered as being in solid solution in the crystals of the ferrite matrix or as forming part of the ever-present "slag streaks." Attention is herein directed to one type of these dissolved impurities, to the detection of such impurities, particularly in low-grade irons, and to their possible influence on the physical properties of the metal. The attention of this bureau was first called to wrought iron of the peculiar and unusual characteristics to be described later, in material which had failed in service and which was submitted for test. The examination was extended to other grades of wrought iron to see whether such features are of common occurrence in this class of material.

II. MICROSTRUCTURE OF WROUGHT IRON.

1. *Usual Structure.*—The general microstructure of wrought iron is so well known that a detailed description of it here is needless. However, for purposes of reference, there is shown in Fig. 2*a*, on page 68, the structure of a sample of Swedish iron. This shows the matrix of ferrite crystals in which are embedded the slag threads so characteristic of the puddling process and the subsequent working of the material. The usual commercial product contains varying amounts of the impurities commonly associated with iron and steel, *i.e.*, manganese, phosphorus, silicon, and sulphur, together with small amounts of carbon. Of these, the larger part of the phosphorus and some of the silicon present are held in solid solution in the ferrite, while most of the remaining impurities, other than carbon, exist in the inclosures of slag. Aside from the discontinuities introduced by the slag streaks, the ferrite matrix has the microstructure and appearance of a pure metal. No definite orientation of the various crystals, or grains, is apparent; deep etching of the specimens reveals no intracrystalline (*i.e.*, within the grains) features other than those noted in "pure" metals in general, *e.g.*, etching pits.

2. *Unusual Features.*—The unusual features noted may be best illustrated by a brief description of the structure of the specimen in which they were first observed in abundance. This piece was a wrought-iron eyebar, a tension member of a railway bridge, which after about 30 years of service was modified to suit the increased traffic, after which modification the member failed. The microscopic examination of the metal revealed, in addition to the usual structure of wrought iron, several features so striking as to mark the sample at once as a wrought iron of very unusual properties and composition.

The ferrite crystals presented a peculiar mottled appearance, particularly after prolonged etching with an acid reagent. This etch pattern was not found over the entire surface of the specimen, but was restricted to certain streaks throughout the metal. Particularly was it found associated with crystals unusually large (Fig. 4*a*, page 68). A series of measurements upon those portions of the material in which such etch patterns were developed in abundance showed the crystals to be as large as 0.25 mm. by 2 mm. A similar set of measurements upon the crystals of the material of Fig. 2*a* showed the average size to be 0.144 mm. by 0.133 mm. The latter set of measurements may be taken as quite characteristic of the grain size of good grades of wrought iron.

The etch pattern referred to above is illustrated in Figs. 1, 2*b*, 3, and 4. By using the copper-chloride etching reagent referred to later these patterns may be developed in a very striking manner. They sometimes consist of broad parallel bands, as seen in cross section, extending across the elongated crystals (Fig. 2*b*) and bearing some resemblance to twinned crystals. More often they present an indefinite mottled appearance of light and dark areas, very similar to the shadows cast by the sunlight streaming through between the leaves of a tree. (Figs. 1 and 3*b*.) The crystals of ordinary wrought iron will not exhibit such etch patterns even after very prolonged etching.

The examination of the metal close up to the fracture which occurred during the service of the material shows that the break occurred through the crystals and parallel to the markings constituting the mottled pattern at that point. Many of the crystals close to the face of the fracture show another variety of intracrystalline markings. On casual examination these may be mistaken for scratches left by poor polishing of the material (Fig. 1, page 68). Closer inspection, however, shows that these markings are parallel to one another within any one crystal and terminate very abruptly at the crystal boundaries. If a slag inclosure lies in the course of one of these markings, the line ends abruptly, reappearing on the other side of the "slag," thus indicating clearly that it is not a scratch. In some crystals a second set, usually not so well developed as the primary ones, is seen. The lines comprising this second set are parallel to one another but form a definite angle with those of the first. Crystals showing markings of this general character in considerable numbers usually present a smoother surface and show less of the shadowlike etch pattern described above than do those crystals in which markings of this class do not occur.

The obvious conclusion is that the nonhomogeneity of the individual crystals as indicated by the mottled etch pattern is to be attributed to some impurity dissolved in the iron but not uniformly diffused throughout the crystal. Robin* has called attention to the fact that in ferrite containing considerable phosphorus, *e.g.*, 1 per cent., such a nonhomogeneity may exist. Stead,† in his extensive studies of the segregation of phosphorus in iron and steel, makes but very slight reference to this type of intracrystalline variation of structure, which Robin attributes to the non-uniform distribution of phosphorus in the ferrite which forms the body of the crystal. Saklatwalla‡ states that the alloys of iron and phosphorus are composed of a single constituent up to a concentration of 1.4 per cent. of phosphorus, consisting of the solid solution of the phosphorus in the iron. Konstantinow's work§ deals primarily with the alloys high in phosphorus, and those low in this element receive but scant attention.

III. MATERIALS EXAMINED.

The variations from the usual microstructure of wrought iron, first noted in the wrought-iron bridge tension member which failed in service, appeared so striking and unusual in character and have been so meagrely described in the literature on the subject that the examination was extended to other grades of iron. From the accumulated series of wrought-iron specimens which have been submitted to the Bureau of Standards from time to time for examination there were chosen some 37 samples for detailed microscopic examination. Much of this material had been submitted as "unsatisfactory," and one of the purposes of the examination was to see whether such material is characterised by microstructural features similar to those noted above. In the following table are listed the materials used. The examination was made by means of Stead's method of etching,* making use of an alcoholic cupric-chloride solution acidulated with hydrochloric acid for etching, by which the segregation of phosphorus is shown by the differential precipitation of copper on the surface of the metal. The precipitation of copper on the areas relatively low in phosphorus is much heavier than on the portions of higher phosphorus content, so that the approximate distribution of this element is rendered visible to microscopic examination. The "high" and "low" phosphorus streaks thus revealed were then examined microscopically to see whether the unusual mottled etch pattern occurred in either.

The results of the examination indicate that the unusual microstructure noted in the failed eyebar, while not to be regarded as a common feature of wrought iron or always associated with iron of inferior grade, is not unique for the single specimen in which it was first

DESCRIPTION OF THE MATERIALS EXAMINED.

Sample No.	Type of material.	Microscopic appearance after cupric-chloride etching.	Microstructure (*a*).	Per cent. of phosphorus.
W 1	Wrought-iron eye-bar, which failed in service.	No copper deposited, surface becomes brown.	Mottled etch pattern is very prominent over most of the surface.	0.856
W 2	Wrought-iron pipe	Copper deposited uniformly over surface.	No mottled areas seen. The metal is to be classed as steel rather than wrought iron.	—
W 3	" " "	" " "	" " "	—
W 4	" " "	Isolated streaks were copper coated; remainder, brown.	Very decided mottled structure in the brown steaks.	—
W 5	"	Outer layers slightly copper coated, central ones slightly brown.	Mottled streaks very prominent in central portion.	(*b*) a, 0.13 (*b*) b, 0.20
W 6	" " "	No copper deposited, surface rather brown	" " "	—
W 7	" " "	No copper deposited, prominent brown streaks.	Mottled appearance across entire face of the section.	—
W 8	" " "	No copper deposited, brown coloration of surface.	" " "	(*b*) a, 0.264 (*b*) b, 0.271
W 9	Wrought-iron "welding" wire.	Copper deposited over all the section.	No mottled areas seen	0.059
W 10	Wrought-iron (?) bar	" " "	No mottled areas seen; the material is really a low-carbon steel.	—
W 11	Wrought-iron pipe	No copper deposited, central streaks very brown.	Mottled appearance of central streaks very conspicuous.	(*b*) a, 0.146 (*b*) b, 0.156
W 12	" " "	Copper precipitated on outer layers; brown streaks in central part.	No mottled areas found	0.123
W 13	Wrought-iron welding wire	Uniform precipitation of copper over the section.	" " "	—
W 14	" " "	Inconspicuous streaks in central portion, otherwise quite uniform precipitation of copper.	" " "	—
W 15	" " "	" " "	" " "	—
W 16	Wrought-iron pipe	No copper precipitated, dark central streaks.	Streaks showing the mottled structure abundant across the section	0.16
W 17	Wrought-iron stay bolt	Some light areas showing method of fagoting; precipitation of copper quite uniform.	Very slight trace only of mottled areas.	—
W 18	" " "	" " "	" " "	—
W 19	Wrought-iron welding wire	Copper uniformly precipitated over surface.	No trace of mottled structure found.	—
W 20	Wrought-iron boiler tube which corroded badly in service.	Copper uniformly precipitated over surface.	No trace of mottled structure found.	0.033
W 21	" " "	" " "	" " "	—
W 22	Low-carbon steel pipe	Central streaks free from copper	Mottled structure very evident in central layers.	—
W 23	Wrought-iron "gooseneck"	Copper deposited quite uniformly over surface.	No mottled areas found; the metal resembles low-carbon steel rather than wrought iron.	0.044
W 24		About 0.7 copper-covered		0.055
W 25		About 0.1 reddened by copper. Other portions show prominent brown streaks.		0.136
W 26		About 0.9 copper-covered		0.079
W 27		About 0.7 copper-covered, with outer portions clear		0.059
W 28		About 0.9 copper-covered		0.073
W 29		Isolated copper-covered streaks aggregating 0.3 total area; other portions clear or brown.		0.112
W 30	Wrought-iron round stock for forging purposes, chains, &c. All but W28 and W 34 were reported to give unsatisfactory results in the preliminary tests of the material.	Surface clear with brown streaks, with one small central copper-covered streak.	No mottled areas were found even in those showing but little precipitation of copper, except Nos. 29, 30, and 36, which show a slight trace.	0.099
W 31		Only a few narrow streaks are copper-coloured, about 0.1 of area.		0.115
W 32		0.1 copper-covered, remainder clear with brown streaks.		0.118
W 33		One fine streak only, copper-coated, prominent dark streaks in remainder.		0.125
W 34		Less than 0.5 is copper-covered; brown streaks in the clear portion.		0.115
W 35		0.8 to 0.9 of area is copper-covered.		0.066
W 36		0.6 area copper-coated, brown streaks in remainder.		0.089
W 37	Link of wrought-iron chain which failed in service.	No copper deposited; surface was coloured brown.	The mottled etch pattern is very prominent throughout.	0.27

(*a*) Under "microstructure" the presence of streaks showing the mottled structure as illustrated by Figs. 2, 3, and 4 is noted and not a complete description of the microstructure.
(*b*) "a" indicates the entire cross section of the sample; "b" the central layer approximating 0.3 in W5 and W 8 and 0.6 in W 11 of the entire cross section.

* Reprinted from No. 97 of Technologic Papers of the Bureau of Standards of the U.S. Department of Commerce.

* Robin, *Traité de Metallographié*, p. 184.

† Jour. Iron and Steel Institute, 140, p. 140; 1915. Stead here summarises his previous work and gives an extended bibliography of the literature on phosphorus in iron.

‡ *Metallurgie*, 5, pp. 336, 711; 1908.

§ *Zeit. für anorg. Chemie*, 66, p. 209; 1910.

* Loc. cit.

observed. It will be noted, however, that such features were found only in material, or portions of such material, which, according to Stead*, are to be regarded as relatively high in phosphorus. The results of the analyses for phosphorus of many of the samples examined are given in the preceding table.

IV. NATURE OF UNUSUAL FEATURES OBSERVED.

1. *Comparison with Iron-Phosphorus Alloys.*—For purposes of comparison, to make certain that the unusual microstructure observed is indicative of a nonuniform distribution of phosphorus, a series of iron-phosphorus alloys was prepared. The phosphorus content ranged from 0.014 per cent. to 0.48 per cent. for the series of six alloys which were made. The preparation of an alloy of so volatile an element as phosphorus offers some difficulties, and a brief description of the method employed will be of instructive interest. Electrolytic iron† which had been melted in vacuo was used. The iron was machined into cylinders approximately three-fourths inch in length and one-half inch in diameter. The centre of the piece was bored out and threaded to receive a threaded plug turned out of the same stock. The desired amount of phosphorus of the yellow variety in the form of sticks was inserted into the cavity, the plug screwed into place, and the whole heated to the melting point of iron in an alundum crucible.

Fig. 6 shows the microstructure of an iron-phosphorus alloy thus prepared containing 0.37 per cent. phosphorus. The metal, in solidifying, freezes selectively, i.e., the solid solution which separates first from the melt is relatively low in phosphorus, and the portions successively added are progressively richer in this element. A eutectic consisting of the solution of phosphorus in iron and iron-phosphide, analogous to pearlite in steel, formed out of the portion which solidified last of all. The alloys containing amounts of phosphorus lower than 0.37 per cent. showed the same general structure as Fig. 6, minus the eutectic.

The equilibrium diagram based on Konstantinow's work‡ is shown in Fig. 5 above. From this, phosphorus is soluble in iron up to about 1.7 per cent., when the system is in equilibrium. Two of the alloys as cast containing 0.37 per cent. and 0.48 per cent. phosphorus, respectively, though far below the limit of solubility, show the heterogeneous character of those above this limit. This heterogeneity of structure in low phosphorus alloys has not been emphasised by Saklatwalla or Konstantinow in their work on this series. The very slow diffusion of phosphorus in the ferrite is the cause of the heterogeneous structure; a condition very apt to prevail in practice, particularly if the heating and working of the material subsequent to the initial rolling is slighted. On annealing the alloy, the eutectic disappears by the phosphide passing into solution in the ferrite, and if the heating is continued the crystal becomes homogeneous by the diffusion of the phosphorus in solution. Upon etching no pronounced mottled etch pattern now appears, only a colouring, yellow or brown, of the surface is seen (Fig. 7*b*).

The comparison of the structure of the iron-phosphorus alloys with that observed in the wrought irons examined is instructive and very suggestive as to the nature of the markings there seen. The dark bands and spots forming the mottled etch patterns are the portions of the ferrite rich in phosphorus, and each individual crystal in the streaks of the metal showing such mottled appearance is to be regarded not as a simple entity but as a rather complex aggregate. That the different portions of a single ferrite crystal in such portions vary considerably in their properties is to be inferred from the marked variation in composition.

2. *Chemical Composition of Materials showing such Features.*—The results of the analyses for phosphorus of many of the materials are listed in the preceding table.

These results show that, though such unusual features of structure as have been described are invariably associated with irons which are rather high in phosphorus, one can not predict with certainty their presence from a knowledge of the average phosphorus content alone. Some of the samples, *e.g.*, W 25, 31, 32, and 33, though comparable with W 11, 12, or 16 in respect to the phosphorus content, showed no traces of these unusual features.

3. *Etching of Samples.*—Upon continued polishing of the specimens before etching, a faint trace of the markings may be seen and recognised by one familiar with this type of iron. This relief polish, however, could not be developed to a degree to permit successful photographs to be taken. The fact that it can be recognised at all, however, is indicative of the differences in hardness which exist throughout those crystals showing this structure.

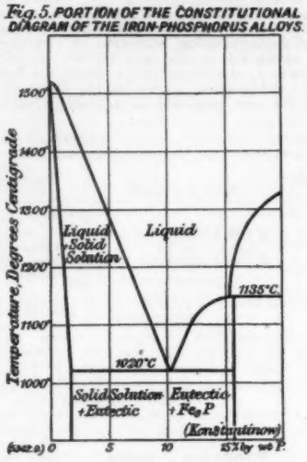


Fig. 5. PORTION OF THE CONSTITUTIONAL DIAGRAM OF THE IRON-PHOSPHORUS ALLOYS.

FIG. 10. HIGH-PHOSPHORUS WROUGHT IRON AFTER ANNEALING.

Specimen W 37 after heating one and one-half hours at 700 deg. C. The nonhomogeneity of structure still persists, though the islands of iron phosphide have been dissolved. Magnification, 66; etching, alcoholic copper chloride acidulated with hydro-chloric acid.

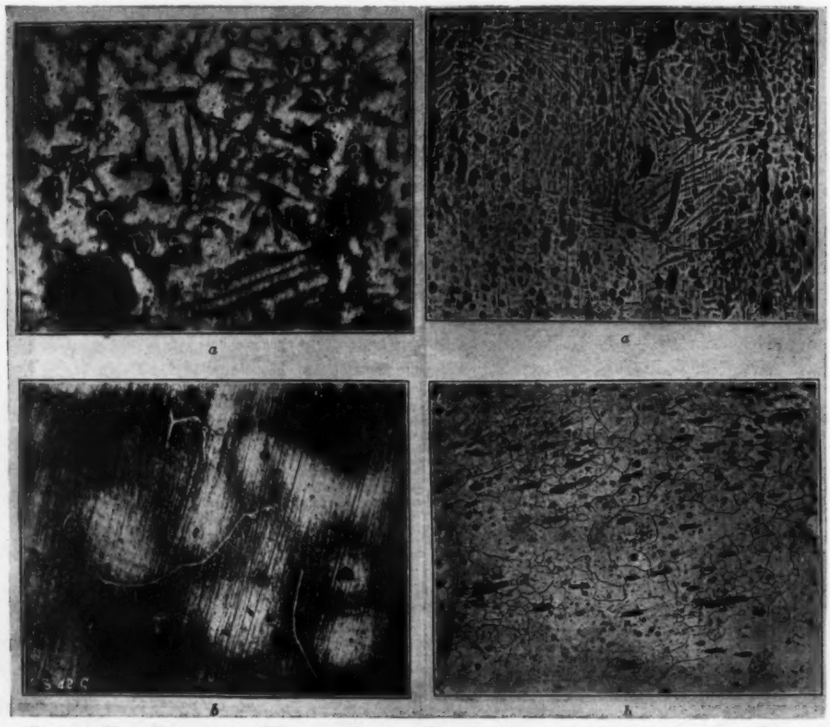


FIG. 8. HIGH-PHOSPHORUS WROUGHT IRON.

(*a*) W 37, longitudinal section. In portions of the material, islands of iron phosphide are found; such islands occur in the centre of the areas which become brown upon etching. Magnification, 66.

(*b*) Same material as *a*. Magnification, 333. Etching in both cases, alcoholic copper chloride containing hydrochloric acid.

FIG. 9. EFFECT OF ANNEALING UPON UNUSUAL FEATURES IN WROUGHT IRON.

(*a*) W 1, heated for three hours at 600 deg. C.

(*b*) W 1, heated for one and one-half hours at 725 deg. C.

Magnification, 66; etching, 10 per cent. nitric acid.

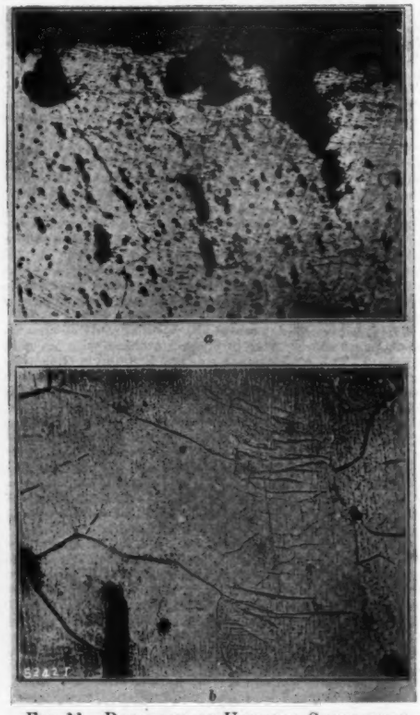


FIG. 11. RELATION OF UNUSUAL STRUCTURAL FEATURES TO THE SERVICE BEHAVIOUR OF THE MATERIAL.

(*a*) Longitudinal section of W 1. The edge of the fracture which occurred is parallel to the bands which constitute the etch pattern here. Magnification, 66.

(*b*) Appearance of very persistent etch lines just back of the fracture in W 1. The specimen has been heated three hours at 600 deg. C. Magnification, 266.

Etching in both cases, 10 per cent. nitric acid.

* Loc. cit.

† Cain, Schramm, and Cleaves, Bureau of Standards Scientific Paper No. 266. Iron prepared as here described was used.

‡ Loc. cit.

By acid etching, preferably using a 5 per cent. or even a 10 per cent. alcoholic solution of nitric acid, the etch pattern may be satisfactorily developed. The specimen shows to the eye the brown and purple tints similar to those which are often observed when hardened and tempered steels are etched with an acid reagent.

By using the cupric-chloride solution described by Stead* the heterogeneous structure may be developed much more strikingly than with acid alone. It was found, however, that the very definite procedure as described by Stead is not necessary; the sample may merely be immersed in an excess of the reagent, as is the usual practice in etching. Ordinarily, when wrought iron is etched with this copper-chloride reagent, it shows the presence of the streaks rich in phosphorus by the deposition of copper on the purer portions, so that the "segregation streaks" appear more lightly coloured in contrast to the matrix. On wrought irons high in phosphorus throughout and in the iron-phosphorus alloys of rather high phosphorus content, *e.g.*, 0.37 per cent. or 0.48 per cent., such a deposition of copper was not observed even after 15 minutes' to 20 minutes' immersion in the etching reagent. The brown tint which results in such cases is very similar in appearance to that obtained with simple acid etching, although the action is more rapid when the copper chloride is used. This coloration has been attributed† to a much-retarded deposition of copper. Several samples of the iron-phosphorus alloys and high-phosphorus layers cut out of wrought iron were etched to a pronounced brown by the copper-chloride reagent by immersing for 20 minutes to 40 minutes. The darkened surface layer was dissolved off with nitric acid after thoroughly washing the specimen, and the resulting solution was tested for copper with potassium ferrocyanide after precipitating the dissolved iron with ammonium hydroxide, filtering off the precipitate and acidifying the filtrate with acetic acid. A faint but clearly perceptible test for copper was obtained.

Though the amount of copper precipitated is very slight, the decided increase of contrast in the etched specimen when the acid copper-chloride reagent is used over that obtained with acid alone warrants the conclusion that it is to the copper that the more rapid etching action and the striking contrast produced is to be largely attributed.

The areas constituting the mottled etch pattern which are darkened are those relatively high in phosphorus, as is plainly indicated in Figs. 6*b* and 7*a*. The ferrite surrounding the iron-phosphide eutectic and that forming part of the eutectic itself constitute the portions which are most strongly coloured and not the less contaminated ferrite which solidified first from the melt. This appears to be in direct opposition to the microscopic results obtained when a sample of wrought iron is etched, in which case copper is precipitated in relatively large amounts upon the layers low in phosphorus. The precipitation of copper upon the streaks of the comparatively pure material is to be attributed to the electrolytic potential of such material with reference to that of copper. The reverse etching of the metal of high phosphorus content can not be so easily explained upon this basis. The action of the hydrochloric acid alone in the reagent as used will develop the etch pattern, although much more slowly than when the copper chloride is present. A trial of the two solutions showed that by a 12-minute immersion in 1 per cent. alcoholic hydrochloric acid a sample of the iron-phosphorus alloy was not etched nearly as satisfactorily as by a 2-minute immersion in the same solution containing copper chloride. The suggestion is offered that metallic copper as such is not deposited, but that there is formed a closely adhering thin film of copper phosphide on the phosphorus-rich portions, and so the result which acid etching alone will produce if enough time is allowed is hastened and intensified. The roughening of the surface by a prolonged acid etching is thus avoided by the use of the copper-chloride solution.

The etching reagent described by Rosenhain and Haughton‡ was tried upon the iron-phosphorus alloys but with unsatisfactory results. It should be noted that if the specimens are mounted in some kind of a matrix for polishing, as is necessary for wires, sections of thin pipe, &c., a matrix of soft alloy or anything of metal must be avoided. The potential difference existing between this metal and the embedded specimen is often so much greater than that between the various portions of the sample under examination as to prevent entirely the differential etching desired.

4. *Behaviour upon Heating.*—The persistence of the unusual intracrystalline structural features upon heating is remarkable. Fig. 9*a*, page 78, shows the appearance of a specimen of the wrought-iron eyebar previously described after heating it for three hours at approximately 600 deg. C. (585 deg. to 625 deg.) and then allowing it to cool in the furnace. No appreciable changes have resulted from this treatment. A second sample (Fig. 9*b*) heated for about 1½ hours at apprximately 725 deg. C. (718 deg. to 735 deg.) and furnace cooled still shows faint traces remaining of the former condition.

Upon heating a sample much higher in phosphorus (W 37) at approximately the same temperature for the same period, *i.e.*, 1½ hours at 700 deg. C. (725 deg. to 690 deg.), the structural change which is brought about (Figs. 8 and 10) is very much less than that shown above. Fig. 8*b* shows the structure resulting from heating an iron-phosphorus alloy, 0.37 per cent. phosphorus, for 24 hours at approximately 790 deg. C., the specimen being allowed to cool in the furnace. The eutectic has disappeared by solution of the compound, Fe_3P, in the ferrite, but the nonhomogeneity of structure as shown by the dendritic pattern still persists. This illustrates well the remarkably slow rate of diffusion within the ferrite matrix by which equilibrium is finally attained. The presence of the compound Fe_3P which had separated out from the matrix most probably accounts for the much slower rate of diffusion in these latter cases than was observed in the case of the first wrought-iron samples which were annealed.

The slow rate of diffusion of phosphorus in ferrite has often been remarked, and it is undoubtedly due to this cause that the mottled structure persists and is not entirely wiped out during the manufacture of the wrought iron, *i.e.*, during the heating, rolling, and forging necessary before the wrought iron reaches the finished condition.

V. Suggested Significance of Unusual Features of Structure.

The significance of the unusual features of microstructure described and their possible relation to the service behaviour of such material may be suggested. The occurrence of material of this type in two of the samples examined (W 1 and W 37), both of which failed in service and which have the appearance of having failed under the action of alternations or repetitions of stress, suggests a possible relation between this type of structure and the failure of such material.

The method by which "fatigue" breaks occur in metals by the action of repeated stresses has been clearly and conclusively set forth by Ewing and Humphrey*, Rosenhain†, and others. The minute back-and-forth slip along certain planes occurring within the crystals if repeated a sufficient number of times becomes a permanent displacement, thus initiating an incipient fracture within the crystal. The combined effect of this action within a number of neighbouring crystals at some portion of the specimen will be sufficient to cause a real fracture to start at that point if the application of the stresses is continued.

The brittle character of ferrite containing considerable phosphorus is well known. Crystals which show the heterogeneity caused by high and low phosphorus bands in juxtaposition should be much more easily "fatigued" by repeated stresses and show a permanent slip much more quickly than crystals which are more uniform throughout in their structure. In particular this should be true if the bands are transverse to the direction of the stresses acting. The observations upon the fracture of the broken eyebar appear to confirm this. Though the evidence shown by the failed member is only "circumstantial," as is always the case in the examination of "metal failures," still so closely does it correspond to and agree with the results of the work of Ewing and Humphrey that there appears little doubt as to the nature of the fracture.

The fact that the face of the fracture followed and its course apparently was determined by the bands within the ferrite crystals has already been referred to. Fig. 11*a*, page 78, shows that the break occurred parallel to the bands of high-phosphorus ferrite which give rise to the peculiar etch pattern. Examination of the metal immediately back of the face of the fracture reveals further evidence. Fig. 11*b* shows the appearance of some of the deepest of the etch bands in the crystals close to the break. These, undoubtedly, represent a stage in which minute transverse cracks, *i.e.*, transverse to the direction of the stresses acting, have opened up within the body of the crystals. The intracrystalline markings obtained by Ewing and Humphrey by subjecting wrought-iron specimens to repeated alternations of stress in the Wöhler test appear in all respects identical with those shown in Fig. 11*b*.

H. H. Campbell‡ quotes the statement that phosphorus up to 0.20 per cent. is not injurious in wrought iron. This should be taken, however, as referring to an average content of this amount uniformly diffused throughout the metal. The microsegregation of this element may result in the amount in certain streaks being considerably in excess of this quantity while within the individual crystals of such streaks the nonhomogeneity with respect to phosphorus is still further accentuated. In the material of Fig. 6*b* the ferrite immediately surrounding the eutectic has a phosphorus content of approximately 1.7 per cent. or nearly five times the average percentage of phosphorus of the sample. It appears very probable, then, that in such nonhomogeneous crystals as are shown in Figs. 2*b* and 3 the high-phosphorus bands may be as much as four or five times the average of the whole (in the percentage of this element) as dertermined by chemical analysis. In exceptional cases portions of a sample high in phosphorus may show traces of iron phosphide that has crystallised out directly from the melt (Fig. 8, *a* and *b*). The metal at such points has a phosphorus content not far below 1.7 per cent., as is indicated in Fig. 5.

The straight lines, resembling polishing scratches, shown by some of the crystals near the fracture (Fig. 1), are the well-known Neumann lines. Such markings are usually considered to be "mechanical" twin crystals, *i.e.*, the twinned position of the metal within each of the narrow zones has been brought about by mechanical causes alone, particularly by shock§ (Fig. 10). They, in all probability, are the result of shock which finally caused the fracture of the bar. A comparison of these lines with the long narrow bands which often constitute the mottled etch pattern shows immediately that such etch bands cannot be attributed to twinning or a similar cause. Much credit is due to W. L. Christian and W. H. Miltner for the careful and efficient work done in the preparation of the many surfaces necessary in the microscopic study. The help received from L. F. Witmer in the chemical analyses of many of the specimens is also acknowledged.

VI. Summary.

1. Wrought irons high in phosphorus sometimes show a peculiar mottled or banded intracrystalline pattern, which, by comparison with alloys of pure iron and phosphorus, is shown to be due to a nonhomogeneous diffusion of the phosphorus.

2. The examination of a wrought-iron member exhibiting such an unusual structure showed that the break which occurred in service bore a definite relation to such banded markings and apparently was largely determined by them.

3. By the nonhomogeneity in the distribution of phosphorus throughout the ferrite crystals the ill effects of phosphorus may be much enhanced.

4. The examination of a series of wrought irons showed that such features are not to be regarded as common or characteristic of all low-grade irons. Many poor grades of iron may be unsuitable for other reasons.

5. A second type of markings is described and illustrated—the well-known Neumann lines—and these are shown to bear no apparent relation to the other variations in structure described.

* Loc. cit.
† Loc. cit.
‡ Jour. Iron and Steel Inst., No. 1, p. 515; 1914.

* Ewing and Humphrey, Phil. *Trans. Royal Soc.*, 200A; 1902.
† Rosenhain, "Introduction to Physical Metallurgy," Chap. VIII.
‡ Campbell, H. H., "The Manufacture and Properties of Steel," page 91.
§ Howe, H. M., and Levy, A. G., *Trans. Am. Soc. Min. Engrs.*, page 891; 1915.

CATALOGUES.

Stock List.—Messrs. Judson-Jackson, 80, Marsham-street, S.W. 1, send a printed list of machines and various supplies actually in stock and showing separately those for which buying permits must be obtained from the Government.

Cutting Compounds.—Messrs. M. and G. Beaumont, Briar-street, Nottingham, send circulars describing their manufactures of oil and compounds for cooling and lubricating metal-cutting tools. These are delivered in a concentrated form and thinned for use with water.

First-Aid Outfit.—Messrs. Alfred Herbert, Limited, Coventry, send a circular stating that they have placed on the market a cabinet containing the various surgical dressings, &c., for minor injuries required by the Home Office Order of October 12, 1917. The contents are prepared by Mr. C. F. Thackray, of Leeds.

Steam Condensers.—A catalogue from Messrs. Cole, Marchent and Morley, Limited, Bradford, deals with condensers of the following types; simple jet, low-level jet, barometric jet and surface, and gives some useful explanatory matter as to the conditions suitable for each type. The various water and air pumps are similarly described, and a number of illustrations are given of condensing plants made by the firm.

Heavy Oil Engines.—Messrs. Cole, Marchent and Morley, Limited, Wakefield-road, Bradford, Yorkshire, send a catalogue giving particulars of their heavy oil engines. Sixteen standard sizes are made ranging from 50 brake horse power to 500 brake horse-power, with one, two, three and four cylinders. These are self-igniting, the air pressure in the cylinder being raised to about 450 lb. before the oil vapour is injected. The cheapest crude or residual oils may be used. The speed is from 210 r.p.m. with the smaller cylinders to 170 r.p.m. with the larger. All these engines are of the vertical type with compressed air for starting.

Herringbone Gears.—The Fawcus Machine Company, Pittsburg, Pa., U.S.A., send a catalogue giving full illustrated descriptions and detailed technical information of their herringbone reduction gears. Teeth up to No. 1 diametral pitch are cut with hobs, and those of larger pitch with a planing machine: both machines being illustrated in the catalogue. Gears of 1 D.P. and smaller are made of 20 deg. involute form with an addendum equal to 0.8 divided by the D.P. and cut at a spiral angle of 23 deg. Larger pitches are cut up to 8 in. circular pitch with varying forms of teeth and, preferably, a flatter spiral angle. The standard ratios cut are 3 to 1, and every complete number up to 12 to 1. The gears are supplied separately or complete in housing, and a flexible coupling for connecting the pinion and power shafts is also described.

Electric Current Converters.—The tendency to make the supply of electrical energy universal is being continually strengthened by mechanical developments, though the problem is not so easy of solution as the Ministry of Reconstruction imagines. For a time it seemed that the fact of long-distance bulk supplies being transmissible only at high tension and in three-phase kind would conflict with the local need for direct current at low voltages. The difficulty is met in two ways: (1) By using the three-phase supply to drive a motor, which, in turn, drives a generator producing direct current: or (2) by the rotary converter, which directly converts the high-tension supply into the low continuous current required. The two methods are explained in a catalogue issued by Messrs. Vickers, Limited, Sheffield. The conclusion is that the rotary converter has now reached such a simple and efficient form that it may safely be much more widely adopted. It can be used to provide either the whole or a supplementary part of the local requirements. The practical side of the matter is very clearly discussed: a full specification with whole and part illustrations is given of the Vickers' rotary converter and a substantial list of places is quoted where the machines are at work in units ranging from 150 kw. to 1,250 kw. French, Russian and Spanish prints of the catalogue are also available.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the Communicators are given in italics.

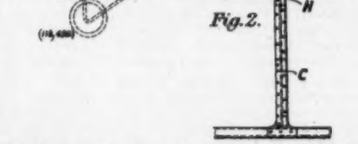
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

AERONAUTICS.

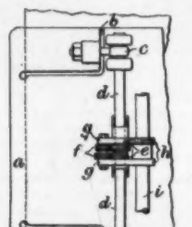
110,433. C. M. Von Eugen, Coventry. Aeroplane Fuselages. (9 *Figs.*) May 10, 1917.—This invention relates to the fuselages of aeroplanes of the kind which are of metal, and comprise the combination of a framework of longitudinal girders and transverse stiffening members connected thereto, and panels to cover the framework. An upper longitudinal girder A is of suitable angular cross-section, and B is a lower longitudinal girder formed of two channelled plates riveted together, back to back. Transverse members C are formed with holes for lightness, and are suitably flanged for stiffness. To the transverse members C are riveted strips H (Fig. 2), which extend right across and are riveted to the upper or lower, or to both upper and lower, longitudinal girders, so as to hold the transverse members firmly in position. The covering panels



are fixed either to the inside or outside of the longitudinal girders, and if desired they can also be fixed to the transverse members. The cowling F is connected to the upper longitudinal girder A or transverse member C, and is readily detachable. The rear fairing G can be integral with the cowling F, or it can be separately connected to the upper longitudinal girder A or transverse members C. A longitudinal stiffening member 1 can be inserted between any pair of transverse members to carry controls or other devices. A stream-lined detachable nose-piece N is connected to the longitudinal girders and a transverse member so as to form a protection for the magnetos if these are fitted to the front of stationary engines. A vertical tubular socket O is provided for the attachment of the fins, or the rudder, or the rear skid. (*Accepted October* 31, 1917.)

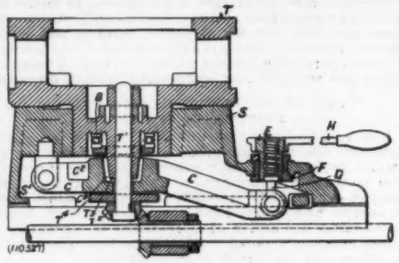
MACHINE AND OTHER TOOLS, SHAFTING, &c.

110,633. James Archdale and Co., Limited, and F. Coxon, Birmingham. Radial-Arm Drilling Machines. (1 *Fig.*) November 15, 1916.—This invention relates to radial-arm drilling machines. The invention comprises the employment of a hand-operated shaft connected to both the locking mechanism and the clutch, the arrangement being such that a longitudinal movement of the shaft actuates the clutch and a rotational movement the locking mechanism. In a machine in which the radial arm slides upon a vertical cylindrical pillar, the sleeve *a* which embraces the pillar is divided at two positions *b*, so that it can be contracted on the pillar. For effecting this movement a known cam device *c* is provided at each division, each cam being mounted on its own shaft *d*. The two shafts are in alignment, and the adjacent ends are connected by an epicyclic mechanism comprising sun pinions *e* on the shafts, planet



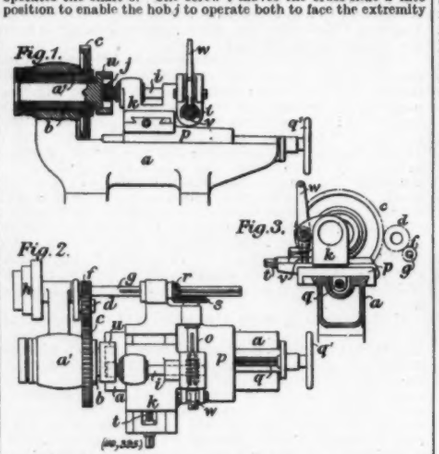
pinions *f* on a spindle which is carried by arms *g*. Each of the latter is formed as a toothed sector at one end and is actuated from a double pinion A through which can slide a shaft *i*, which is feather-keyed to the pinion. At one end the shaft is connected to a lever which actuates a clutch in conjunction with the automatic raising and lowering mechanism of the arm. On the other end a hand lever is provided for actuating the shaft. In conjunction with the lever or any other convenient part of the shaft or of the mechanisms associated with it, suitable provision is made for preventing actuation of the shaft before the arm is unlocked or locking of the arm before the clutch is put out of action. Rotation of the shaft operates the locking mechanism without affecting the clutch, and endwise movement of the shaft operates the clutch without affecting the locking mechanism. (*Accepted November* 7, 1917.)

110,527. B. J. Spink and A. Lease, Shipley. Lathes. (1 *Fig.*) July 11, 1917.—This invention relates to turrets for lathes. T represents the turret and S the saddle. The turret revolves with a spindle T^1, carrying a bevel wheel T^2 at its base in the usual manner. In a recess of the shank of the turret T, ball bearings B are mounted. In a recess S^1 in the base, a lever C, carrying a hollow boss C^1, hollowed out as at C^2 to receive the downward projecting portion T^3 of the turret, is pivoted to the saddle. The other end of the lever C projects to one side of the saddle and carries an upstanding threaded eyebolt D, said bolt D being pivotally attached to the end of lever C. The bolt D passes upwards through an internally-threaded nut E, to which a handle H is secured. The nut E is also externally threaded, say, with an ordinary Whitworth thread, and the thread engages a bush F secured in the saddle S. This arrange-



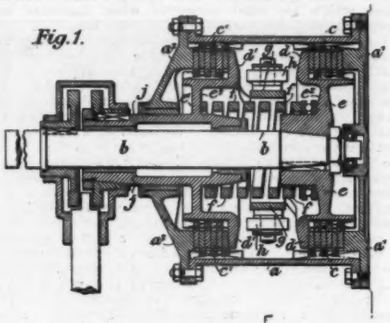
ment gives a compound movement and enables the necessary power and quick movement to be obtained when the handle H is operated. If the bolt D is lifted upwards by turning the handle H the boss C_2 will also be lifted and raise the turret clear of its seat when the turret may be revolved on its ball bearings, and is clear of its seat and from frictional contact therewith. If the bolt D be depressed, the boss C_2 will fall and its lower face be pressed against the wheel plate T^4. The turret will come down on to its seating and be locked. (*Accepted October* 31, 1917.)

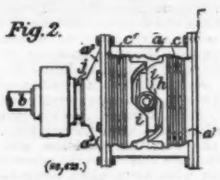
110,395. G. Richards, London, and W. W. Beaumont, Westminster. Milling Screw Threads. (5 *Figs.*) October 16, 1916.—This invention relates to milling screw threads on the internal surfaces of cylindrical or conical bodies by means of a rotary cutter, known as a "hob," and formed with cutting teeth which follow a screw thread corresponding in pitch with that of the thread to be cut. In the headstock a^1 of the machine frame *a* is mounted a hollow spindle *b* furnished with a toothed wheel *c* which, through an intermediate-toothed wheel *d*, derives rotative motion from a pinion *f* carried by the shaft *g*. The shaft *g* is driven at various speeds by means of the cone pulley *h*. The arbour *i*, which carries the hob *j*, is mounted in a carriage *k*, and is driven by a worm wheel and worm; the latter sliding on the shaft *o*. The carriage *p* has a longitudinal movement on the bed of the frame *a*, and is actuated by the screw *q* and hand wheel q^1. The shaft *g*, on which the bevel pinion *r* is arranged to slide on a spline, drives the bevel wheel *s*, and this in its turn operates the shaft *o*. The screw *t* moves the cross-slide *k* into position to enable the hob *j* to operate both to face the extremity



of the piece of work *u* and to cut the thread in the internal surface of the projecting neck thereof. The spur gear *f*, *d*, *c*, are so designed in relation to the bevel and worm gear, whereby the hob *j* is driven, that the same rotative speed is normally imparted to the work and to the hob. This equality of rotative speed is, however, capable of slight variation in the following manner. The worm is formed with a tubular extension provided with collars *v*, between which the forked end of a lever *w* works. Upon the lever *w* being vibrated the worm is moved axially upon the shaft *o*, with the effect that the rotative speed of the hob *j*, transmitted through the said worm, is slightly increased or slightly diminished. The effect of this is to produce a slight "creep in advance" or a slight "creep in arrear" of the normal rotative speed of the hob and to prevent the formation of facets upon the work. The total to and fro' movement of the worm should be such as to accelerate or to retard the peripheral speed of the hob to an extent equal to about the distance between the cutting edges of two consecutive teeth of the hob employed. (*Accepted October* 31, 1917.)

110,673. A. G. Langdon, Northam, Southampton. Friction Clutches and Brake Mechanism. (5 *Figs.*) January 20, 1917.—This invention relates to friction clutches and brakes of the Weston plate or disc type. *a* denotes the casing of the clutch, and a^1 denotes the end-plate of the casing, by which the clutch may be connected to the flywheel of an engine, or directly to the shaft of a driving engine or motor, or to a belt pulley or the like. a^2 designates the after end-plate of the casing, and *b* designates the shaft to be driven. *c*, c^1, denote the duplex nests of friction discs of the Weston type; the discs are made alternately of phosphor bronze and mild steel, or cast-iron, and are placed between the inner circumference of the casing *a* and the flanges d, d^1, provided on the disc members *e*, e^1. These disc members *e*, e^1, are provided with annular spaces e^2, e^3, between which there is mounted a spiral spring *f*; round the spiral spring there is provided a ring *g*, on which are mounted rollers A; these rollers A are adapted to bear on the inclines i, i^1, provided on the discs *e*, e^1. *j* denotes a sliding sleeve-member which forms part of the disc e^1, which is constructed so as to slide on the shaft *b* and apply pressure to, or remove pressure from, the friction discs c^1. This sliding sleeve together with the disc members *e*, e^1, causes the rollers A to apply or remove pressure from the Weston discs *c*, c^1 as the

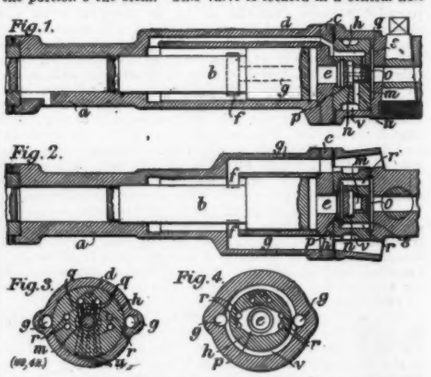




clutch is operated. The spiral spring *f*, which is placed between the sleeve member *j* and the back part of the disc member *e*, against which it bears, on release effects the reaction, which restores the parts to the normal position. (*Accepted November* 7, 1917.)

MINING, METALLURGY AND METAL-WORKING.

110,411. R. De H. St. Stephens, Camborne, and Climax Rock-Drill and Engineering Works, Limited, Carn Brea. Rock Drills. (7 *Figs.*) October 27, 1916.—The invention relates to valve gear for rock drills, and other percussion tools, and to that class of such gear wherein the valve proper has two parts of different diameters which control two ports only. *a* indicates the working cylinder, *b* the hammer piston and *c* the rear cover. *d* is the passage through which the air enters and is exhausted from the front end of the cylinder. *e* is the opening in the cover *c* through which the air enters the rear end of the cylinder *a*, and *f*, *f*, are ports through which the air is exhausted from the rear end of the cylinder, and which communicates with passages *g*, *g*, formed in the cylinder walls and through the cover *c*. *h* is the valve chest which is applied to the rear face of the cylinder cover *c*. *m* is the valve arranged according to the invention, and which, is formed with two portions of different diameter, the portion *n* constituting the head of the valve and the portion *o* the stem. This valve is located in a central hole



bored in the valve chest and having the parts of different diameters in which the parts *n*, *o*, respectively, slide. *p*, *q*, are ports, the port *p* extending entirely around the said valve chest and being in open communication through the passages *r*, *r*, with a recess *s* behind the valve chest in open communication with the air supply, whilst the port *q* communicates with the passage *d* in the cylinder wall. The positions of these ports with respect to the valve are such with relation to the driving fluid supply passage *e* that when one port is uncovered by the valve the other is covered. A groove is formed in the stem of the valve *m* and *u* is a port which communicates with the portion of the valve chest in which the stem slides and also with an exhaust passage, which latter is in the form of a circumferential groove *v* around the valve chest, communicating at all times with the exhaust passages *g*, *g*. With the arrangement described it will be seen that the rear end *o* of the stem of the valve *m* is always exposed to the driving fluid supply, whilst the head of the valve is always directly open to the cylinder. (*Accepted October* 31, 1917.)

THE NIEDERLAUSITZ LIGNITE DISTRICT.—The large Petschek concern continues to extend its influence within the German lignite district of Niederlausitz, a movement which is not viewed with much favour in Germany. Following upon recent requirements of lignite deposits by the two Petschek undertakings, the Eintracht lignite works and the Niederlausitz coal works, a further purchase in the Niederlausitz district has now been made, viz., that of the Germania concern in Sarchen, for a price of 2,000,000 marks. The reason for the two deals referred to above was stated to be the desire to secure sufficient future reserves, but it is pointed out, that this cannot apply to the acquirement of the Germania which is an independent lignite field in full work and with its own briquette factory.